Frontispiece]

View of the bridge of a modern battleship, showing the general lay-out of instruments, from a photograph reproduced by the courtesy of Mr. Charles E. Brown.

[*See* Chapters VIII, IX and X.

ADMIRALTY NAVIGATION MANUAL

VOLUME I

1938

LONDON
HIS MAJESTY'S STATIONERY OFFICE
Price 10*s.* 0*d.* net

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

To be purchased direct from
H.M. STATIONERY OFFICE at the following addresses:

York House, Kingsway - - -	London, W.C.2
13a Castle Street - - - - - -	Edinburgh 2
39–41 King Street - - - - - -	Manchester 2
1 St. Andrew's Crescent - - - - - -	Cardiff
80 Chichester Street - - - - - - -	Belfast

or through any bookseller

1939

(*Reprinted* 1944)

Price 10*s.* 0*d.* net

The Lords Commissioners of the Admiralty have decided that a new Admiralty Navigation Manual is required for the information and guidance of the Officers of His Majesty's Fleet; for this purpose the present Manual has been compiled in three volumes under the direction of the Captain, H.M. Navigation School, Portsmouth, by the Staff of H.M. Navigation School assisted by the Dean and Staff of the Royal Naval College, Greenwich.

By the publication of this Manaul, the Admiralty Manual of Navigation, 1928, is superseded and may be destroyed.

BY COMMAND OF THEIR LORDSHIPS.

*Admiralty, S.W.*1.
October, 1937.

PREFACE

The Admiralty Navigation Manual, 1938, consists of three Volumes:

Volume I is a practical guide for executive officers covering the syllabus laid down for examination in Navigation and Pilotage for the rank of Lieutenant, but omitting the study of nautical astronomy.

Volume II is the text book of nautical astronomy completing the above syllabus.

Volume III is based on the syllabus for officers qualifying in Navigation and deals solely with advanced subjects and mathematical proof not included in Volumes I and II. It will be unnecessary for executive officers in general to study this Volume.

Thanks are due for the information given by the Hydrographic Department, the Naval and Marine Divisions of the Meteorological Office, various instrument manufacturers, and to Messrs. Rich and Cowan for the use of extracts from *On the Bridge*, by Captain J. A. G. Troup, R.N.

CONTENTS

CHAPTER

POSITION AND DIRECTION ON THE EARTH'S SURFACE

CHAPTER II

DESCRIPTION OF ADMIRALTY CHARTS AND PUBLICATIONS

CHAPTER III

THE SHIP'S TRACK

CHAPTER IV

FIXING BY TERRESTRIAL OBJECTS AND TIDAL STREAM PROBLEMS

CHAPTER V

FIXING BY W/T–D/F

CHAPTER VI

RULE OF THE ROAD

CHAPTER VII

NAVIGATION IN PILOTAGE WATERS; BUOYS, LIGHTS AND FOG SIGNALS

CHAPTER VIII

NAVIGATIONAL INSTRUMENTS

CHAPTER IX

THE GYRO COMPASS

CHAPTER X

THE MAGNETIC COMPASS

CHAPTER XI

CHRONOMETERS AND WATCHES

CHAPTER XII

TIDES AND TIDAL STREAMS

CHAPTER XIII

ELEMENTARY METEOROLOGY

CHAPTER XIV

SYNOPTIC CHARTS AND WEATHER FORECASTING

CHAPTER XV

THE OCEAN

APPENDIX I

THE SEXTANT AND BUBBLE SEXTANT

APPENDIX II

NOTES ON SIGHTS

APPENDIX III

EXAMPLES OF SIGHTS

APPENDIX IV

APPENDIX V

HINTS TO THE NAVIGATING OFFICER

CHAPTER I

POSITION AND DIRECTION ON THE EARTH'S SURFACE

Navigation is the science which enables a ship to be conducted from place to place in safety, and her position to be determined by observations of terrestrial or celestial objects, or by other methods.

That part of navigation which is concerned with the open sea and observations of heavenly bodies is fully dealt with in Volume II of this Manual.

The purpose of this Volume is to describe that part of navigation which is particularly concerned with *pilotage* or the conduct of a

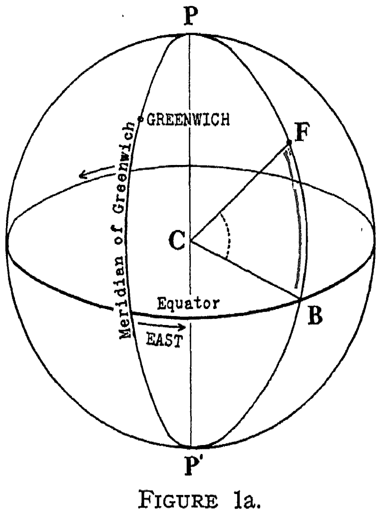


FIGURE 1a.

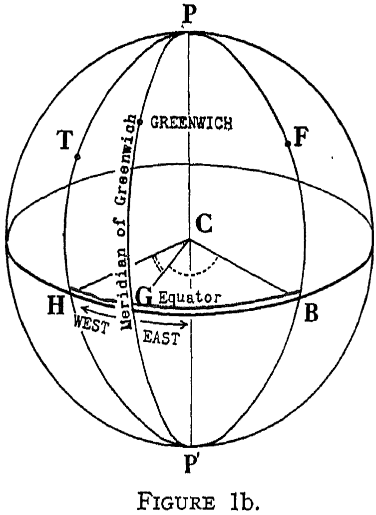


FIGURE 1b.

ship in the neighbourhood of dangers, such as rocks, shoals and narrow waters.

This necessitates a knowledge of charts, sailing directions, etc., and also of artificial aids to navigation such as buoys, lights, fog signals, etc.

Full descriptions of the following definitions which are illustrated in figures 1a and 1b will be found in Chapters I and II of Volume II.

The Earth. Although the Earth is not a perfect sphere, it may be considered one for the purposes of navigation because the errors which result from the assumption are usually negligible. The departures from the spherical shape are explained fully in Volume III.

The Poles of the Earth. P and P′ are the extremities of the Earth's axis of rotation.

East and West. The direction in which the Earth rotates is called *east;* the opposite direction is called *west.*

The North Pole. P is that extremity of the Earth's axis, viewed from which the Earth rotates in an anti-clockwise direction.

The South Pole. P′ is the other extremity of the Earth's axis. The axis P′P lies very nearly in the same direction as a star known as the Pole Star or Polaris.

The Equator is the great circle midway between the poles. Every point on the equator is therefore 90° from the poles.

> NOTE. A sphere is formed by rotating a circle about a diameter. Any section of a sphere by a plane must therefore be a circle. If the plane goes through the centre of the sphere, the resulting section is the largest that can be obtained and is known as a GREAT CIRCLE. It is important because it gives the navigator the shortest track between any two places that lie on it. If the plane does not pass through the centre of the sphere, the section is known as a SMALL CIRCLE.

Meridians are semi-great circles joining the poles, and are perpendicular to the equator.

UNITS OF MEASUREMENT

A Nautical Mile at any place is the length of one minute of arc measured along the meridian through the place.

It varies in different latitudes owing to the irregular shape of the Earth. In practice it is taken to be 6,080 feet, which is its value in latitude 48°.

A Knot. In navigation the unit of speed is a knot, which is a speed of one nautical mile per hour.

A Cable is one-tenth of a nautical mile; in practice it is taken as 200 yards.

A Statute or Land Mile is an arbitrary unit introduced by Queen Elizabeth, who decreed that it was to be 8 furlongs of 40 perches of 16½ feet—5,280 feet, that is.

A nautical mile is thus larger than a statute mile by about one-seventh, and seven nautical miles are equivalent to approximately eight statute miles.

Latitude. The latitude of a place is its angular distance from the equator and is measured in degrees and minutes north and south of the equator. In figure 1a the latitude of a place F is the angle FCB, north of the equator.

Longitude. The longitude of a place is the angular distance along the equator between the meridian through Greenwich and the meridian through the place. It is usually measured east or west of the Greenwich meridian in degrees and minutes from 0° to 180°,

but it may also be measured in hours, minutes and seconds from 0 to 12 hours.

In figure 1b the longitude of a place F is the angle GCB, east of Greenwich; and the longitude of a place T is the angle GCH, west of Greenwich.

THE PROBLEM OF COURSE FINDING

Direction is determined by the point on the horizon towards which a person is aiming or a vessel is moving. It is thus essentially a line.

The cardinal directions are north, south, east and west.

Bearing. To the navigator of a ship in mid-ocean, the horizon is a circle drawn about the ship as centre, and there is nothing to

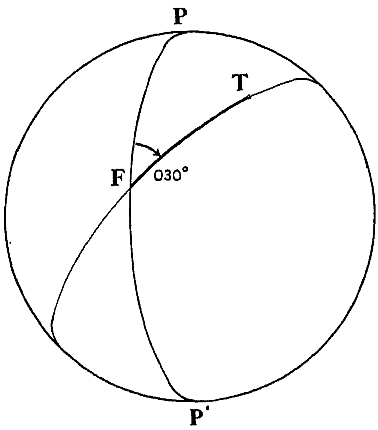


FIGURE 2a.

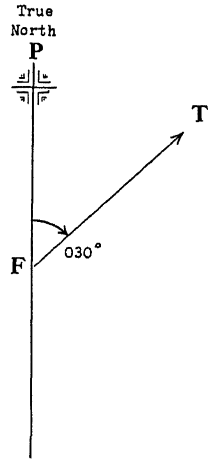


FIGURE 2b.

distinguish one point on that circle from another. In order to proceed in a particular direction it is therefore necessary to refer to some datum line or fixed direction. The *angle* between this datum line and the direction in which it is required to proceed is called the *bearing* of the point towards which the ship is proceeding.

True Bearing. The most convenient datum is the meridian through the ship's position, because that is the north–south line. Bearings measured from this datum are known as *true bearings*.

In figure 2a, FP, the meridian through F, gives the direction of true north. FT, the great circle joining F to T, gives the direction of T. The angle PFT is the true bearing of T from F.

If T is close to F, the small area of the Earth's surface traversed by FT may be considered flat, and no appreciable error will be introduced if the great circles are drawn as straight lines, as in figure 2b.

The angle PFT is always measured clockwise from 0° to 360°, and it is always written as a three-figure number in order that the bearing may be recognised immediately as a true one. In figures 2a and 2b, T would be said to bear 030° from F.

In figures 3a and 3b, T bears 330° from F, and the point N, which lies on the meridian through F and therefore due north of F, bears 000°.

True Course. The direction in which a ship moves in still water is the direction of her fore-and-aft line. The angle between this

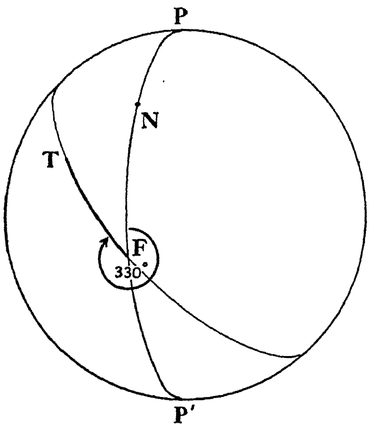


FIGURE 3a.

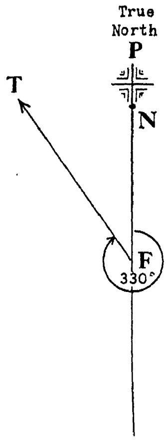


FIGURE 3b.

fore-and-aft line and the meridian through her position is called her *true course.* The bearing of the ship's head is thus the same as her course.

THE COMPASS

The navigational compass is an instrument that gives the necessary datum line from which courses and bearings can be measured. There are two kinds of compass :

1. the gyro compass.
2. the magnetic compass.

The Gyro Compass. This instrument, which is described in Chapter IX, is essentially a heavy and rapidly spinning wheel or gyroscope, the axis of which is made to point approximately true north. Thus in the gyro compass the navigator has an instrument which will indicate the direction of the true north by pointing along the true meridian. Bearings taken with a gyro compass will therefore be true bearings, and will always be referred to as three-figure numbers. To enable this to be done the outer rims of the gyro compass repeaters. with which bearings are taken, are graduated clockwise from 000° to 360°.

Error of the Gyro Compass. For a number of reasons the gyro compass will seldom point exactly to the true north. It may settle a degree or two on one side or the other of the true meridian, and if it does the compass will be said to read *high* or *low*. The methods of finding the error of the gyro compass are given in Chapter IX.

Suppose the compass is checked on an object the true bearing of which is known to be 075°. If the gyro bearing is 077°, it is clear from figure 4a that the gyro is reading *high* and the error, therefore, is 2° high : if the gyro bearing is 073° it is clear from figure 4b that the gyro is reading *low* and the error is 2° low.

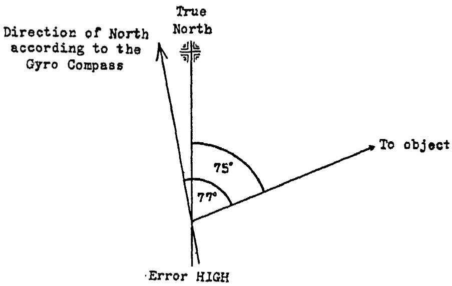


FIGURE 4a.

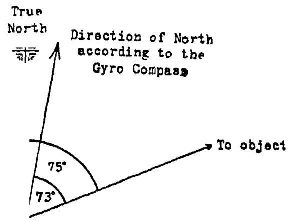


FIGURE 4b.

The Magnetic Compass. This instrument, which is described in Chapter X, is a bar magnet freely suspended. Being thus unrestrained, it turns and settles with one end pointing approximately to the north. It will not, as a rule, point to the true north because the Earth's geographical or true poles do not coincide with the magnetic poles to which the ends of the compass needles are attracted.

Lines of force pass between these poles forming what may be termed *magnetic meridians*, and it is along the particular magnetic meridian passing through the magnetic compass that the needle of the compass will settle.

Variation. The angle between the true meridian and the magnetic meridian at any place is called the *variation* at the place.

Variation is said to be *easterly* if the direction of the magnetic north lies to the east of the true meridian, and *westerly* if it lies to the west. It is expressed in degrees and minutes of arc.

In figure 5, the variation at F would be about 20° west.

In practice the navigator obtains the variation either from the navigational chart which he is using, or from a special *isogonic* chart on which all places of equal variation are joined by what are known as isogonic lines. An isogonic chart is reproduced in Chapter X. On ordinary charts the variation is given for a certain year, together with a note of any annual change which it is undergoing. If, therefore, the navigator is using an old chart, he must allow for this annual change.

The variation in the Bristol Channel, for example, is given on Admiralty Chart No. 2675a as being 15°25′ west in 1928 and decreasing about 12′ annually. In 1937, therefore, it will be 15°25′ less (9×12′) which is approximately 13½°.

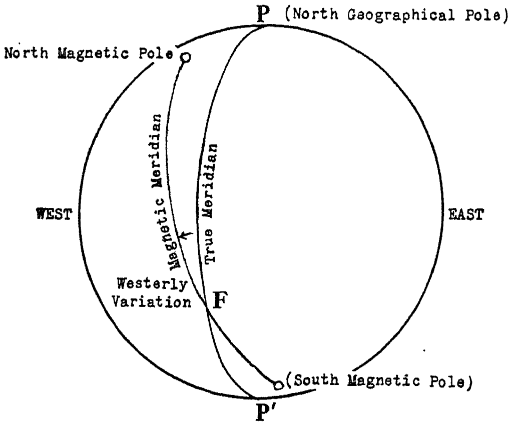


FIGURE 5.

Magnetic Bearing. By magnetic bearing is meant the angle between the direction of the place or object in question and the direction of the magnetic north. Thus, in figure 6a, the magnetic bearing of T from F is the angle between the great circle FT and the magnetic meridian through F.

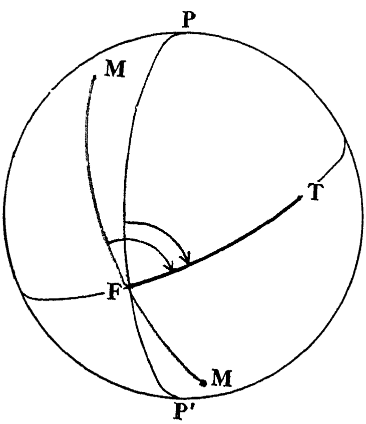


FIGURE 6a.

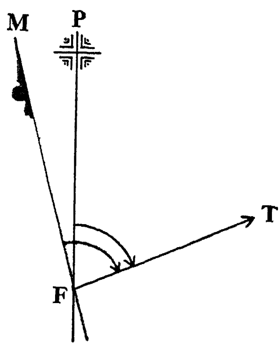


FIGURE 6b.

In order to distinguish between true and magnetic bearings, the latter are always given with reference to the cardinal points—north, south, east and west—and not as three-figure numbers.

In figure 6b, the magnetic bearing of T from F (that is the angle MFT) is about N.85°E., whereas the true bearing (the angle

PFT) is about 065°. The difference between these two angles is the variation.

The magnetic bearing of a place or object is therefore—to enlarge the definition—the angle between the direction of magnetic north or south, and the direction of the place or object measured east or west from 0° to 90°.

NOTE. The custom of distinguishing magnetic bearings by referring them to the cardinal points merely carries on the practice of navigators before the invention of the gyro compass. The compass card was then divided into 32 points—north, north by east, north-north-east, north-east by north, and so on; the naming of the 32 in their correct order being known as 'boxing the compass'—and the navigator of the old sailing ship would tell the man at the wheel to steer, say, 'north-west by west', which is equivalent to N.56¼°W., since a point is clearly 11¼ degrees. The term 'point' is still used with that significance.

Deviation. If a magnetic compass is put in a vessel built of iron or steel, the presence of so much metal will cause the compass needle

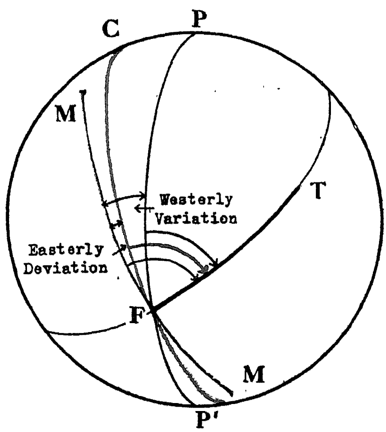


FIGURE 7a.

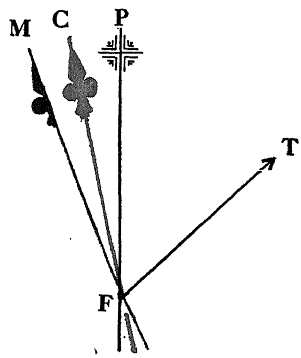


FIGURE 7b.

to deviate from the magnetic meridian. The angle between the magnetic meridian and the direction in which the needle actually points, is called the *deviation*.

The direction in which the compass actually points is known as *compass north* to distinguish it from magnetic north and true north.

If compass north lies to the east of the magnetic meridian, the deviation is said to be *easterly*; if to the west, it is said to be *westerly*.

Compass Bearing. By compass bearing is meant the angle between the direction of compass north or south, and the direction of the place or object in question, measured east or west, from 0° to 90°. Thus, in figure 7a, the compass bearing of T from F is the angle between the great circle FT and the direction in which the compass is pointing.

In figure 7b the compass bearing of T from F (that is the angle CFT) is about N.55°E., whereas the magnetic bearing (the angle MFT) is about N.65°E. and the true bearing (the angle PFT) is about 045°. The angle MFC is the deviation (about 10° east) and the angle PFM is the variation.

It should be borne in mind that whenever a navigator uses a magnetic compass on board a ship, he obtains a compass bearing, and he must correct it for both deviation and variation in order to arrive at the true bearing.

Change in Deviation. The magnetic compass is usually placed on the bridge, that is, nearer to the bows than to the stern. The iron and steel in the ship is therefore not symmetrical in relation to it, and every time the ship alters course, that iron and steel will change its position relative to the compass and so attract or repel the needle a different amount. The deviation will therefore change for every alteration of course.

Deviation Table. The actual amount of this deviation for any direction of the ship's head can be found by 'swinging ship' as described in Chapter X, and it is reduced if necessary by placing permanent magnets and soft iron correctors at the compass, as described in Chapter X. It is not possible, however, to correct the entire deviation in this way, but that which remains can be shown conveniently in the form of a table. Thus :

Compass direction of ship's head.	Deviation.
N.	2½° W.
N.N.E.	3 ° W.
N.E.	3 ° W.
E.N.E.	2½° W.
E.	1½° W.
E.S.E.	½° W.
S.E.	½° E.
S.S.E.	1½° E.
S.	2½° E.
S.S.W.	3½° E.
S.W.	3½° E.
W.S.W.	3 ° E.
W.	2 ° E.
W.N.W.	1 ° E.
N.W.	NIL
N.N.W.	1½° W.

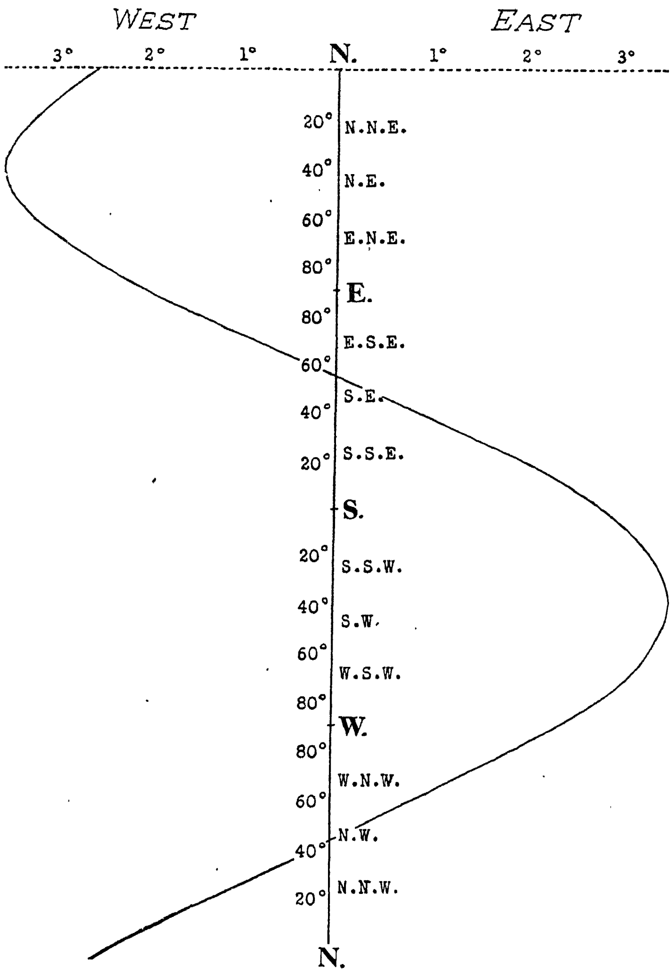
The method of correcting the compass (explained in Chapter X) is by swinging the ship through successive angles of 22½°, and the deviation table is made out for these intervals.

The deviation for a direction of the ship's head lying between any two given in the table can be found by simple interpolation. Thus, if the deviation is required for S.80°W., the table shows that it is between 3° E. (the deviation for W.S.W.) and 2° E. (the deviation for west) : the actual amount is just over 2°.5 E.

Deviation Curve. If the above deviation table is arranged in the form of a graph—the deviation being plotted against the compass direction of the ship's head—a deviation curve is obtained.

Conversely if a deviation table for every ten degrees is required, it can be made out from a deviation curve.

DEVIATION CURVE



The deviation curve has a slight advantage over the deviation table in that the deviation for any intermediate direction of the ship's head can be found by inspection.

Note. In practice a standard compass should never have deviations of this size; they should always be less than 2° if the compass is properly corrected.

The Ship's Course. The course of the ship is, strictly, the direction in which she is moving through the water—the direction,

that is, of her fore-and-aft line—and her course-angle is the angle between that direction and the direction of true, magnetic or compass north. It is customary, however, to speak of the course-angle as the course, and all that has been said about the bearing, which is also an angle, may be said about the course.

True Course. This is the angle between the direction of true north and the ship's fore-and-aft line, measured clockwise from 0° to 360°. (Angle PFB in figure 8.)

Magnetic Course. This is the angle between the direction of magnetic north or south and the ship's fore-and-aft line, measured east or west from 0° to 90°. (Angle MFB in figure 8.)

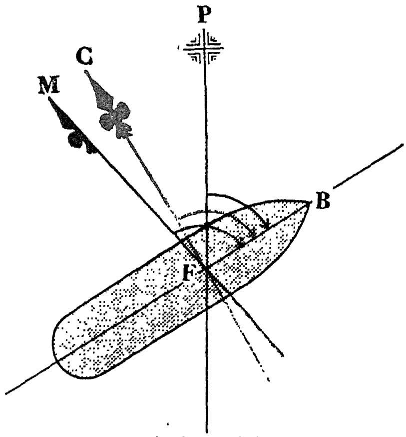


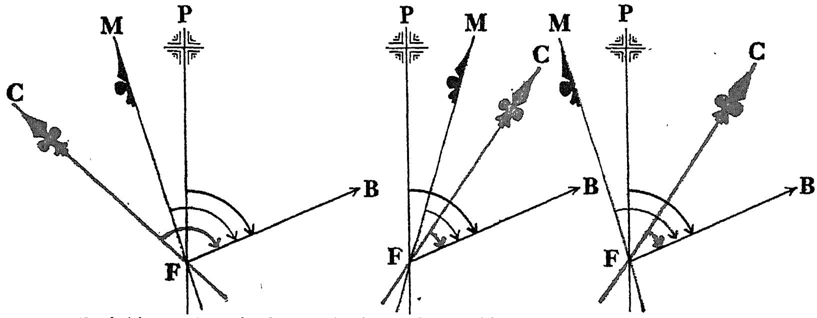
FIGURE 8.

Compass Course. This is the angle between the direction of compass north or south and the ship's fore-and-aft line, measured east or west from 0° to 90°. (Angle CFB in figure 8.)

NOTE. In considering the alterations in a ship's course, it must always be remembered that she herself turns round the compass, and that beyond adjusting itself for deviation· the compass needle does not move. The bowl of the compass is therefore fixed in the ship, and a mark called the LUBBER'S POINT is made on it in order to indicate the fore-and-aft line.

Correction of Courses and Bearings. In practice the navigator is faced with the problem of finding the true bearing, say, when he has taken the compass bearing, or of finding the compass course when he has worked out his true course. That is, he must apply the variation and the deviation. The first is found from the chart for the year in question. The second is found from the table or curve *for the compass direction of the ship's head,* and it is essential to bear this in mind when a compass bearing is corrected. The compass bearing of an object may be S.23°W., but if the compass direction

of the ship's head is N.72°E., then the deviation applied to S.23°W. must be taken out for N.72°E. because the deviation table or curve is based on the compass direction of the ship's head.



Variation and Deviation both Westerly — Variation and Deviation both Easterly — Variation Westerly and Deviation Easterly

FIGURE 9a. FIGURE 9b. FIGURE 9c.

To Find the True Course from the Compass Course. In the above figures FB is the direction of the ship's head ; the compass course is the angle CFB ; the magnetic course is the angle MFB ; and the true course is the angle PFB.

In figure 9a, the magnetic course is clearly less than the compass course by the amount of the westerly deviation ; and the true course is less than the magnetic course by the amount of the westerly variation. Therefore, to find the true course, the *westerly* deviation and variation must be *subtracted* from the compass course.

In figure 9b, the magnetic course is clearly greater than the compass course by the amount of the easterly deviation, and the true course is greater than the magnetic course by the amount of easterly variation. Therefore, to find the true course, the *easterly* deviation and variation must be *added* to the compass course.

In figure 9c, the magnetic course is clearly greater than the compass course by the amount of the easterly deviation, and the true course is less than the magnetic course by the amount of the westerly variation. Therefore, to find the true course, the *easterly* deviation must be *added* to the compass course and the *westerly* variation *subtracted* from it.

Since no restriction has been placed on the size of the angle CFB beyond that it is measured from *compass north*, the rule for converting a compass course into a true one therefore suggests itself.

Consider easterly deviation and variation as plus and westerly deviation and variation as minus, and add them to or subtract them from the compass course measured, for the purpose, not as an angle between 0° and 90° from the cardinal points, but as an angle between 0° and 360° measured from compass north.

A ship, for example, is steaming S.30°W. by magnetic compass. Her deviation table shows that the deviation is 3°E., and the chart shows that the corrected variation for her position is 12°W. What is her true course ?

S.30°W. by compass is	210°	from compass north
Easterly deviation	3°	plus
Westerly variation	12°	minus
True Course	201°	

Again, suppose the ship is steaming N.45°W. by magnetic compass. Her deviation table shows that the deviation is 5°W. and the chart shows that the variation is 8°E.

N.45°W. by compass is	315°	from compass north
Westerly deviation	5°	minus
Easterly variation	8°	plus
True Course	318°	

To Find the Compass Course from the True Course. To do this, the signs in the above rule must be reversed; that is, westerly variation and deviation must be considered positive, and easterly variation and deviation as negative. There is, however, a small complication. Before the navigator can find his compass course he must know the deviation. But he cannot take out his deviation until he knows his compass course. He therefore takes out an approximate deviation for his magnetic course, and, if necessary, a second and more accurate one when he has found what is really an approximate compass course.

NOTE. If the compass is closely corrected, by the method explained in Chapter X, the deviations should not be large enough to make this second approximation necessary.

Suppose, for example, a navigator worked out his true course as 208°. The variation is 12°W. What course must he steer by compass ?

True course	208°	
Westerly variation	12°	plus
Magnetic course	220°	from magnetic north

This may be written S.40°W. (magnetic), and if he enters the deviation table on page 8 for that course it is seen that the approximate deviation is $3\frac{1}{2}$°E.

Magnetic course (as above)	220°	from magnetic north
Easterly deviation	$3\frac{1}{2}$°	minus
Compass course	$216\frac{1}{2}$°	from compass north
	or S.$36\frac{1}{2}$°W.	

If he now enters the deviation table with this approximate compass course he obtains a deviation of 3·4°, and a more accurate compass course would be S.36·6°W. But since he would tell the quartermaster to steer to the nearest half degree—that is S.36½°W.—it would not be necessary to trouble about one-tenth of a degree.

To Lay off a Compass Course or Bearing on the Chart. Most charts have what are known as compass roses printed on them.

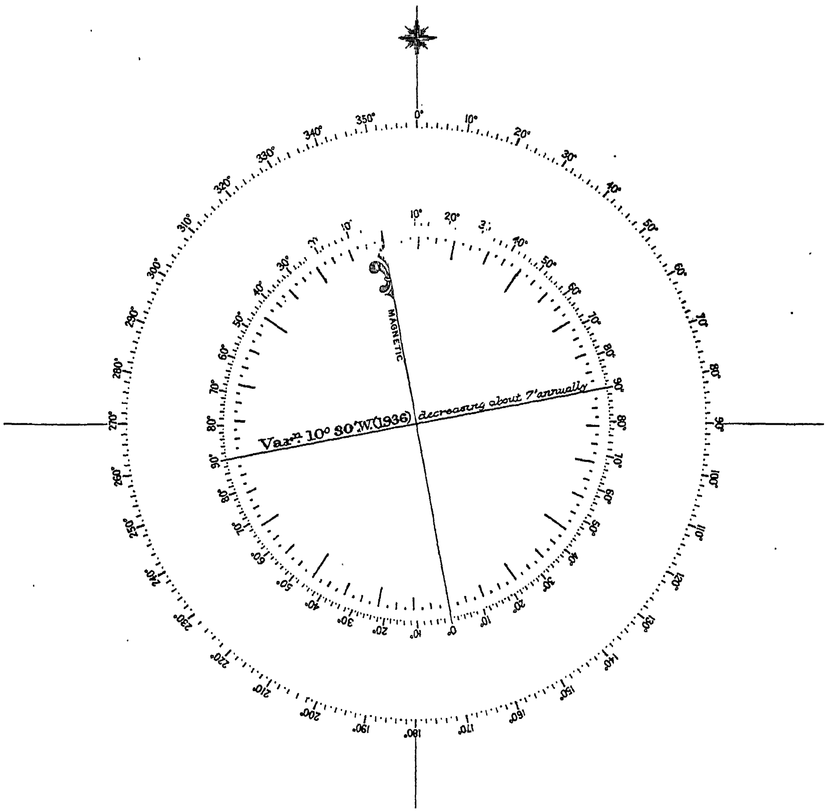


FIGURE 10.

The outer represents the true compass, and the inner the magnetic one, as shown in figure 10.

On the east-west line of the magnetic rose is written the variation, the year for which it is correct, and its rate of change.

Before he can use this magnetic rose for laying off a compass course, the navigator must therefore apply both the deviation and the change of variation. This can be done conveniently in one step by combining the deviation with the change of variation and then applying the result as an error to the magnetic rose.

Suppose, for example, in 1937 the compass bearing of an object is S.23°E., the deviation 3°W. and the variation from the chart 17°W. in 1932, decreasing 9′ annually. The change in variation during 5 years is 45′E. The error to be applied to the magnetic rose is therefore (3°W.−45′E.) or $2\frac{1}{4}$°W. That is to say, compass north lies $2\frac{1}{4}$° to the west of magnetic north, and this may be taken into account by placing the parallel rulers (with which the bearing is laid off) on the magnetic rose in the direction of S.23°E. and then slewing them *anticlockwise* through $2\frac{1}{4}$°, since, in order to pass from magnetic north to a compass north to the west of it, the movement must be anticlockwise. The reading on the magnetic rose—that is, the adjusted magnetic course—is thus S.$25\frac{1}{4}$°E.

To check this, apply the rule for correcting courses and bearings.

Compass bearing is S.23°E. or	157° from compass north
Westerly deviation	3° minus
Magnetic bearing	154° from magnetic north
Easterly change in variation	$\frac{3}{4}$° plus
Magnetic bearing adjusted to chart	$154\frac{3}{4}$° from chart magnetic north
	that is, S.$25\frac{1}{4}$°E.

In effect, this method of applying an adjusted deviation to the compass course or bearing and then using the magnetic rose, saves the navigator the trouble of making calculations on paper, because he has merely to add or subtract two small quantities and slew his parallel ruler that amount. The rule to be followed is thus :

If the combined deviation and change of variation is westerly, the ruler must be slewed anticlockwise ; if easterly, clockwise.

Should it be required to know the compass course to steer in order to steam along a certain line on the chart, the above precedure must be reversed. By placing the parallel rulers along this line and running them to the nearest magnetic rose, a magnetic course is obtained for the variation used in the rose, and to this course must be applied the deviation corrected for any change of variation. Thus, suppose that in 1937 it is required to steer a course which, as read off the magnetic rose, is N.68°E., and that the deviation is 3°E. and the variation 8°W. in 1932, decreasing 9′ annually. What is the compass course ?

The change of variation in 5 years is 45′E. The error to be applied to the magnetic rose is therefore $3\frac{3}{4}$°E. That is, compass north lies $3\frac{3}{4}$°E. of magnetic north ; the compass reading is less than the magnetic, and the parallel rulers must be slewed that amount anticlockwise, thereby giving on the magnetic rose a reading of N.$64\frac{1}{4}$°E.

To check this by rule :

Magnetic bearing by chart is N.68°E. or	068 °	from chart magnetic north
Easterly change in variation	$\frac{3}{4}$°	minus
Magnetic bearing	067$\frac{1}{4}$°	from magnetic north
Easterly deviation	3 °	minus
Compass bearing	064$\frac{1}{4}$°	from compass north

that is, N.64$\frac{1}{4}$°E.

(Note that in this example the rule applied is the reverse of the one used in the example on page 14.)

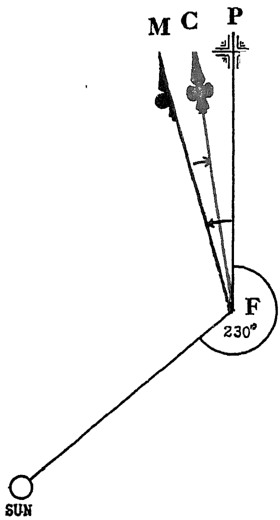


FIGURE 11.

To Check the Deviation. Suppose a compass bearing is taken of an object, the true bearing of which is known. Then, if the variation is also known, the deviation can be found and compared with that obtained from the deviation table or curve.

The true bearing of the Sun, for example, can be found by methods which are explained in Volume II. Suppose it is 230° as shown in figure 11, the compass bearing at the same moment being S.55°W., and the variation 12°W. Then :

True bearing of Sun	230°	
Westerly variation	12°	plus
Magnetic bearing of Sun	242°	from magnetic north
Compass bearing of Sun	235°	from compass north
Deviation	7°	minus *and therefore easterly*

Relative Bearings. Bearings of objects are frequently given, not with reference to the true, magnetic or compass north, but to the fore-and-aft line of the ship. They are then said to be red or green according as the object, and therefore the bearing, lies to port or starboard. These are known as relative bearings.

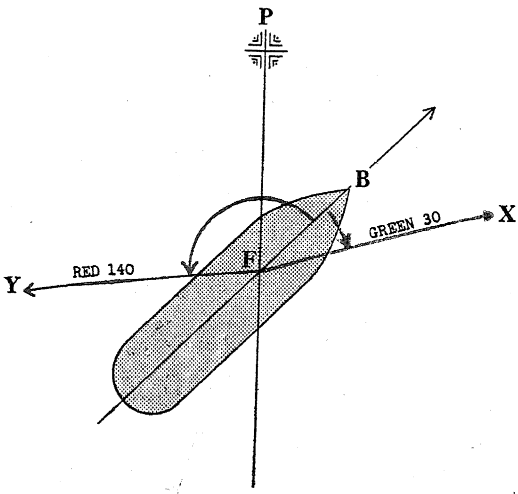


FIGURE 12.

In figure 12, the bearing of X is Green 30°, and of Y, Red 140°. If the ship herself is steaming 045°, then the true bearing of X is 075° and of Y, 265°. Alternatively X could be said to be 30° on the starboard bow, and Y 40° on the port quarter.

The expressions, *on the bow*, *on the beam* and *on the quarter* without any specified number of degrees or points, mean respectively 45° or 4 points, 90° or 8 points, and 135° or 12 points from the ship's head.

CHAPTER II

ADMIRALTY CHARTS AND PUBLICATIONS

ADMIRALTY CHARTS

The Hydrographic Office of the Admiralty was instituted in 1795 for the production of navigational charts.

Its twenty-five departments now contain technical branches dealing with such matters, in addition to the Admiralty charts, as *Sailing Directions*, Tides, *Light Lists*, *Notices to Mariners*.

Attached to the chart branch are several naval assistants and experienced surveying and navigating officers, whose duty is to study the daily flow of hydrographic information which comes through correspondence, foreign notices and similar channels, and to deal with these, more particularly with reference to matters of such navigational urgency as require announcement by *Notices to Mariners* and the immediate correction of the chart plates.

The Hydrographic Department produces approximately 4,000 different charts, which may be grouped into the following categories:

1. navigational charts, on which the ship's track is plotted.
2. non-navigational charts, which cannot be used for plotting the ship's track.
3. plotting sheets.

NAVIGATIONAL CHARTS

Charts Drawn on the Mercator Projection. Most charts are drawn on the *Mercator Projection*, a full description of which is given in Volume II.

A line on the Earth's surface which cuts all the meridians at the same angle is called a *rhumb line*. If, therefore, two places on the Earth's surface are joined by a rhumb line and the ship steers along this line, the direction of the ship's head will remain the same throughout the passage. This direction is determined by the angle from the meridian to the rhumb line, measured clockwise from 0° to 360°, and is called *the course*. The rhumb line is also, itself, often spoken of as the course.

The principle of the Mercator projection is that all rhumb lines are represented by straight lines and from this it follows that on Mercator charts:

1. the equator is shown as a straight line.

2. meridians within the limits of the chart (see the note in Volume II) are shown as parallel straight lines perpendicular to the equator.

3. the course between two places appears as a straight line.

It is further evident that the scale of latitude and distance increases with the latitude until at the poles it is infinite. For example, on a Mercator chart of the world, Iceland with an approximate diameter of 260 miles appears to be the same size as Borneo with an approximate diameter of 600 miles; *hence it must be remembered that the Mercator projection does not show the correct relation between distances measured in different parts of the chart, unless they are in the same latitude, and, therefore, it is not possible to take off distances from the margin at random.*

This projection is used for all Admiralty charts having a natural scale smaller than 1/50,000 ; *a scale, that is, less than* $1\frac{1}{2}$ *inches to one mile.*

NOTE. The natural scale is the ratio of a length measured on the chart to a corresponding length measured on the Earth's surface.

Charts drawn on the Gnomonic Projection. A full description of this projection, which is a true geometrical projection, is given in Volume II.

The chart is drawn on a flat surface, touching the Earth at one point, usually the central point of the chart, which is known as the tangent point.

Lines are drawn from the centre of the Earth, through points on the Earth's surface, until they reach the flat surface of the chart. Hence:

1. great circles are straight lines on the chart.
2. meridians are straight lines converging to the pole.
3. parallels of latitude are curves.
4. the farther a point on the chart is away from the tangent point, the greater will be the distortion.

NOTE. The marginal lines of the chart are usually drawn parallel and at right angles to the central meridian instead of being drawn parallel to the marginal meridians.

This projection is used for:

(*a*) great-circle sailing charts.

(*b*) polar charts.

(*c*) charts of a natural scale larger than 1/50,000 ; a scale, that is, greater than $1\frac{1}{2}$ inches to one mile.

Harbour Plans. These plans are a special form of gnomonic chart, the small area of the Earth concerned being treated as flat.

The latitude and longitude of the 'observation spot', or some prominent object, is given under the title, and on an ungraduated plan the position of any other point can be laid down by noting its difference of latitude and longitude from the observation spot, these

differences being measured on the separate scales of latitude and longitude shown on the plan.

To construct a Scale of Longitude on a Plan. If a scale of longitude is not given it can be found from the ordinary cosine-secant construction.

From the 0 on the scale of latitude draw a line making an angle with it which is equal to the latitude of the place, as shown in figure 13. From each division on the scale of latitude drop perpendiculars to this line. The intersection of these perpendiculars with the line mark the scale of longitude.

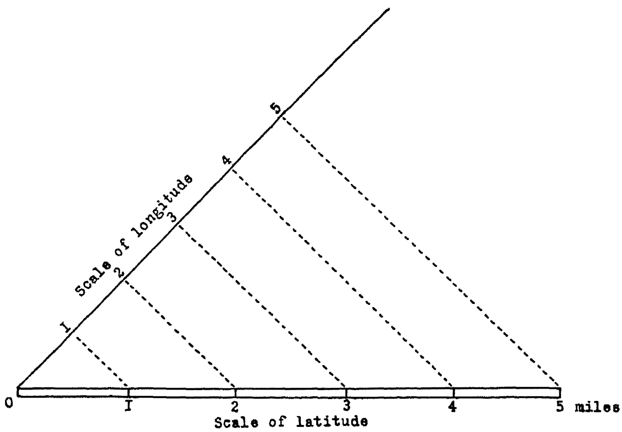


FIGURE 13.

Figure 13 shows the construction for a scale of longitude when the place is in latitude 45°.

Exercise Charts. These charts, which are drawn on the Mercator projection, are supplied for fleet exercises. They contain no soundings or land contours, etc.

NON-NAVIGATIONAL CHARTS AND PLOTTING SHEETS

Non-Navigational Charts. These consist of:

1. meteorological charts.
2. ice charts.
3. telegraph and W/T. station charts.
4. magnetic variation charts.
5. oceanic sounding charts.
6. reference chart folios for Flag officers.
7. chart atlas folio for W.R. officers, in charge of the junior executive W.R. officer.
8. chart atlas folio for G.R. officers in charge of the senior executive G.R. officer.
9. chart atlas folio for the ship's company in charge of the navigating officer or officer appointed by the Captain.
10. special instructional charts.

Plotting Sheets. These consist of:

1. mooring boards.
2. diagrams 5004 and 5004a.

PRINTING AND DISTORTION OF CHARTS

The process of printing is fully described in a pamphlet entitled *How the British Admiralty Charts are Produced*, and is also referred to in Volume III of this Manual. The original work of a chart is usually engraved on a copper plate. If a small quantity of charts is required, they may be printed from this plate, but before this is done, a thin coating of steel is deposited on the copper to protect the plate from wearing away.

Many charts are, however, required in large quantities, and in these circumstances, for economy as well as to avoid damage to the original copper, and for other reasons, the work is transferred from the copper plate to a zinc plate.

Charts printed from zinc plates are called lithographic impressions, although the adjective strictly refers to an impression taken from stone and from nothing else.

The paper on which a chart is printed from a copper plate has to be damped so that the ink will take, and when it dries there may be distortion. When printed from zinc the paper is damped only the slightest amount and is much less liable to distortion than it is when printed from copper.

A good *check on the distortion of a chart* is to test its dimensions by the actual plate measurements, which are given *in brackets at the lower right-hand corner* outside the margin; on recent charts these measurements are given between the inner lines of the graduation.

All lithographic impressions printed from zinc (since October, 1925) bear in the *lower right-hand corner* a Z with the year in which the transfer was made from the copper plate (c). Thus: Zc 1927.

Other small letters, in addition to c, that are found on charts, namely, p., e., s. or z., mean that the original from which the printing plates are transferred was a process plate, electrotype, stone or zinc respectively, but any chart on which a Z or S appears in the lower right-hand corner, with or without additional small letters, is a lithographic impression and may be assumed to be almost free from distortion.

Clearly, in a given measured distance, the effect of distortion decreases as the scale increases and will have the least effect on large-scale charts. Moreover, the copper plates of large scale charts are brought up to date before the plates of small-scale charts, and so for these, and many other reasons, which will be described later, *the largest-scale chart available should always be used.*

INFORMATION SHOWN ON CHARTS

Admiralty chart 5011 gives an explanation of the signs and abbreviations used on Admiralty charts. A copy of this chart is in the back of this Volume.

The Date of Publication	is shown outside the bottom margin of a chart in the middle.
The Dates of New Editions **The Dates of Large Corrections**	are shown to the right of the date of publication.

The Date of Printing is shown in the right-hand top corner; thus 135.37 indicates that the chart was printed on the 135th day of 1937.

The Number of the Chart is shown in the right-hand bottom corner, and also on the label on the back of the chart.

The Dimensions of the Chart in inches between the inner lines of the graduation are shown in brackets outside the margin in the bottom right-hand corner. These are useful for checking the dimensions of the chart on that of the original plate, should distortion be suspected.

Small Corrections to the Chart may be shown in the following ways:

1. When a chart is corrected from information promulgated in an *Admiralty Notice to Mariners* (except temporary and preliminary notices) the year, if not already shown, and number of the notice are entered in the bottom left-hand corner of the chart, thus:

Small corrections 1936—903—

Charts in stock in the Admiralty Chart Establishment and the Admiralty chart depots are corrected by hand from this information.

2. When a chart is corrected from information which is considered of no importance to safe navigation and is therefore not promulgated in an *Admiralty Notice to Mariners*, the year, if not already shown, and the date of correction are entered on the chart in one of two ways in the bottom left-hand corner below the margin and in sequence with the notations referred to in the preceding paragraph. Thus:

Small corrections 1936 5.20 — or *Small corrections* 1936—(VI.25)—

These indicate that the chart received minor corrections on the 20th May or 25th June, 1936.

The Units used for Depths are stated in bold lettering under the title of the chart. On modern charts, soundings under 11 fathoms are given in fathoms and feet.

Heights on the chart are given in feet above mean high water springs.

Depths are given below the chart datum, which is approximately the level of mean low water springs unless otherwise stated.

Underlined Figures on Banks denote the number of feet the bank dries above chart datum.

The Date of the Survey is given under the title of the chart.

A Conversion Table of Feet into Metres is shown on some charts.

The Latitude and Longitude of the Observation Spot or some other prominent object is given under the title of a plan.

Tidal information for various ports on the chart is printed in a table in a suitable position.

Tidal Stream Information

1. All information about tidal streams, whether in tables, or in notes giving the times of slack water and the rate of the tidal streams, is given in some convenient place on the chart and referred to by a special symbol—A for example—at the position for which the tidal stream information is given. The letter in the diamond gives the reference to the tidal stream information.
2. Tidal stream information is shown by means of tidal stream arrows on certain charts when information suitable for the tabular form is not available. The arrows are referred to in Chapter XII.

To describe a Particular Copy of a Chart. When describing a particular copy of a chart, state in the following order the :

1. number.
2. title.
3. date of publication.
4. date of the last new edition.
5. date of the last large correction.
6. number, or date, of the last small correction.

To distinguish a Well-Surveyed Chart. Bear in mind the following points :

1. the survey should be reasonably modern.
2. soundings should be close together and regular, with no blank spaces.
3. fathom and contour lines should be shown.
4. there should be plenty of detail and contour lines, etc.
5. all the coastline should be drawn in, with no dotted line indicating lack of information.

HINTS TO REMEMBER WHEN USING CHARTS

1. Always use the largest-scale chart, because :
   - (*a*) any errors are reduced to a minimum.
   - (*b*) if the chart is distorted, these errors will have the least effect.

(c) more detail is shown.
(d) the plate from which it is made is corrected before the plates of small scale charts.

2. Transfer positions from one chart to another by bearing and distance from a point common to both charts and check by latitude and longitude. This is most necessary because the graduations on the two charts may differ.
3. Always fix the ship's position as soon as possible after her position has been transferred from one chart to another.
4. Always use the nearest compass rose because :
   (a) there will be less effect of distortion and the correct variation will be used.
   (b) an error will be avoided if the chart used is drawn on the gnomonic projection.
5. Remember the change of variation printed on each compass rose.

THE ARRANGEMENT OF CHARTS

The Chart Folio. Outfits of charts required by ships and establishments are normally supplied in folios. The charts in each folio are arranged in geographical sequence as far as possible, and are contained in a limp canvas cover.

Folios of ordinary charts are numbered according to the geographical area for which they provide. This number is the *folio number*. Each folio is also given a *serial number* to distinguish the folios which have the same folio number from one another.

These numbers and the contents of the folio are shown on the following forms, which are pasted on the outside of the folio cover :

1. **A folio label** showing the folio and serial numbers, and also the date of the original issue of the folio from the Admiralty Chart Establishment, and the subsequent dates of issue from the chart depots.
2. **A folio list** showing the numbers of the charts contained in the folio with their titles, also the titles of the appropriate *Sailing Directions* and, occasionally, other appropriate publications. Duplicate lists are supplied in a springback.

   A column is left blank on the folio list for noting the *consecutive numbers* of the charts as arranged in the folio, in order to facilitate, in conjunction with H.51, the removal of the charts from, and their re-insertion in, the folio.

A small label, known as the *chart label*, is pasted on the back of each chart. It shows the number and title of the chart and provides spaces for noting the folio number, serial number of the folio, and the consecutive number of the chart in the folio.

The Age Limit of Chart Folios. The effective age of chart

folios is limited to six years from the date of their *original* issue, with the restriction that navigational folios do not have more than four years' continuous service afloat. The replacement of all time-expired folios is arranged by the Admiralty Chart Establishment.

Waterproofed Charts for Dockyard Use. Small dockyard craft employed solely within the limits of the dockyard ports at home and abroad are supplied, if required, with specially waterproofed copies of local charts instead of with chart folios.

Index to Charts Contained in Folios. Since the number of a chart provides no ready clue to the geographical area for which the chart provides, a special index is published in the *Handbook on the Supply and Correction of Admiralty Charts, Sailing Directions, etc.* (H.51.)

This index enumerates the folios in which the charts will be found, and provides space for inserting the consecutive numbers of the charts.

To bring this index into use it is necessary to complete the consecutive number columns on the folio lists and then insert the corresponding numbers in the handbook.

NOTE. 1. The consecutive numbers of the charts must also be inserted on the chart label and on the duplicate folio lists.

2. All the consecutive numbers should be inserted in black lead pencil to facilitate subsequent amendments.

3. The sign † against a folio number in H.51 indicates that the chart is omitted from that folio if another of the folios containing the same chart is already held.

SUPPLY, UPKEEP AND DISPOSAL OF CHART FOLIOS AND PUBLICATIONS

Full information is given in H.51, and the officer responsible for a ship's charts should study the instructions given in this handbook.

Admiralty Chart Depots are established at the following places :

Home Station
- The Admiralty Chart Establishment, London, N.W.2.
- H.M. dockyards at Sheerness and Portsmouth.
- The Royal William yard, Plymouth.

Abroad
- H.M. dockyards at Gibraltar, Malta, Simonstown, Singapore and Hongkong.

Forms Used with Charts and Publications

H.74 .. Supply voucher.
H.11 .. Receipt certificate.
H.81 .. Transfer certificate.
H.38 .. Demand note for charts.
H.177 .. Demand note for publications.
H.80 .. Supply and receipt note for charts and publications issued by the Hydrographic Department, Admiralty.

1. **The First Supply of Charts to a Ship.** The officer superintending the building or repairing of ships in home waters is to report to the Hydrographer the date on which chart folios, etc., will be required, and to which rail address they should be forwarded. The outfit will be supplied from the most convenient chart depot, which will not necessarily be at the port from which the navigating party is drawn. (K.R. and A.I. 1196 (i).) For ships abroad, recommissioning or proceeding to another station, chart folios, etc., should be demanded from the chart depot on the station. Should there be no chart depot, the outfit will be sent from England. (K.R. and A.I. 1196 (2).)

2. **Boxes.** Outfits are supplied to ships in special boxes These boxes form an integral part of the outfit and should not be used for any other purpose. They should be retained on board with the outfit, but if this is impossible they should be returned to a chart depot.

3. **State of Correction on Supply.** The charts are normally corrected up to date, except for temporary and preliminary notices, and the date of the last correction is shown on the folio labels and on the supply voucher (H.74). The publications are not corrected when issued, but are accompanied by all the necessary supplements and summaries of notices.

4. **Checking the Outfit.** When the charts have been checked by the folio lists, and it is confirmed that all the publications have been received, the receipt certificate (H.11) should be signed and returned to the issuing chart depot.

5. **Correction from Temporary and Preliminary Notices.** To enable the charts to be corrected in pencil for temporary and preliminary notices when they are received, the following are supplied with the outfit:

(*a*) a copy of the latest list of temporary and preliminary notes that are still in force.

(*b*) a copy of the pamphlet containing copies of all such notices in force at the end of the preceding year.

(*c*) a set of the *Weekly Complete Edition of Notices to Mariners* for the current year. These are also required for correcting the publications.

(*d*) a copy of any temporary and preliminary notice affecting the outfit, published since the last weekly edition.

SUPPLY OF CHARTS AND PUBLICATIONS TO A SHIP ALREADY HOLDING AN OUTFIT

In these circumstances, the information given under 'First Supply' 2, 3, 4 and 5 also applies, except that the *Notices to Mariners* 5, (*b*) and (*c*), which should already be onboard, are not again supplied.

Subsequent Upkeep of Outfits in Ships. After the first supply of an outfit from a chart depot, replenishments are supplied from the Admiralty Chart Establishment.

The following points should be noted.

1. Daily *Notices to Mariners* are issued to ships when it is considered necessary to promulgate navigational information urgently, and they should receive immediate attention. They are distinguished by the notation (H) at the top right-hand corner, and are repeated in the *Weekly Complete Edition.*
2. *Weekly Complete Editions of Notices to Mariners.* These notices are fully described on page 28. Form H.133 is used as a supply and receipt note.
3. Charts. New charts, new editions and new copies are supplied as necessary, and the receipt of such charts to which the ship is entitled can be checked by reference to the weekly *Notices to Mariners.* Should one of these charts be received shortly before or after a *Notice to Mariners* affecting it, care must be taken to make the correction, if necessary, after comparing the number of the notice with the notation of small corrections on the chart. Form H.80 is used as a combined supply and receipt note.
4. On receiving a chart issued for the first time, always note its arrival in:
   (*a*) H.51.
   (*b*) the folio list.
   (*c*) the duplicate folio list.
   (*d*) the index chart in the *Sailing Directions.*
   (*e*) the body of the *Sailing Directions.*
5. Publications. New editions of *Sailing Directions,* and supplements and summaries of *Notices to Mariners* affecting them and other publications are supplied as necessary. The receipt of all publications to which the ship is entitled can be checked by reference to the weekly *Notices to Mariners.*
6. Worn or damaged charts and publications are replaced on demand. Demands for charts should be made on Form H.38 and for publications on Form H.177 addressed to the Admiralty Chart Establishment. Chart depots at home are not allowed to deal with such demands, and abroad they are authorised to deal with them only if they are urgent and if spare copies of the chart or publication are available.
7. Local purchases of charts and publications should not be made except when there is an unforeseen emergency. Such purchases should be at once reported to the

Admiralty Chart Establishment. In these circumstances the charts, etc., should be obtained if possible from a sub-agent. These sub-agents have instructions to supply charts and *Sailing Directions* free of charge. but they require a receipt. (See *Notice to Mariners* No. 2 published each year.)

Transfers of chart folios and publications from one ship or establishment to another, or to a chart depot, should be notified immediately on a transfer certificate (H.81) to the Admiralty Chart Establishment so that replenishments may be averted.

The following forms should also be completed.

1. A supply voucher (H.74) should accompany folios, etc., transferred from one officer to another or to a chart depot. With navigational outfits it is necessary to certify on this voucher that the outfit has been properly corrected up to the latest *Notice to Mariners* received, the number of which should be shown.
2. A receipt certificate (H.11) certifying that the chart folios, etc., are complete should be made out in duplicate when folios, etc., are received from another officer. One copy should be sent to the Admiralty Chart Establishment, and another copy given to the supplying officer.

Disposal of Outfits on Paying Off. When the ship is ordered to pay off and recommission immediately, the outfit should be retained for the next commission.

When a ship is ordered to pay off and when she will not recommission at once, the Admiralty Chart Establishment should be asked for instruction about the disposal of the outfit.

If the ship is in foreign waters, the outfit should be returned to the nearest chart depot, and the transfer reported to the Admiralty Chart Establishment.

NOTICES TO MARINERS

Admiralty Notices to Mariners contain information primarily for the correction of Admiralty charts, *Sailing Directions, Light Lists* and the *Admiralty List of Wireless Signals.*

Notices are published daily and are numbered consecutively, starting at the beginning of each year.

They are also issued as two separate weekly editions and one quarterly edition. These will be described in detail.

A certain number of *Daily Notices* are issued to the Hydrographic Department, chart depots, chart agencies, and the Board of Trade. They are issued to ships only when it is necessary to promulgate navigational information urgently and when this occurs they are distinguished by the notation (H) at the top right-hand corner. They are repeated in the *Weekly Edition.*

Weekly Complete Editions of Admiralty Notices to Mariners. These editions are for H.M. ships and foreign-going merchantment They have a number at the top of the front page corresponding to the week of the year, and they are divided into four parts which contain the following information:

Section I. An index to the *Notices to Mariners,* arranged in geographical sections.

Section II. A list of temporary and preliminary notices in force. This list is given only in the edition for the last week of each month.

A list of *Sailing Directions* and supplements published and under revision. (Issued monthly.)

A list of new charts, new editions etc., published, and charts thus affected. (Issued weekly.)

Notices to Mariners published during the week, arranged in geographical sections.

Section III. Corrections to the *Admiralty List of Lights.*

Section IV. Corrections to the *Admiralty List of W/T Signals.*

In addition to the above, the *Weekly Complete Edition* No. 1 of each year contains information and warnings about a number of points. These vary from time to time, but in general they include a caution to ships approaching the British Isles, together with instructions for the examination service and signals to be shown by vessels engaged in minesweeping; the latest list of sub-agents for the sale of Admiralty charts; general information about mines, especially those in the North Sea and the vicinity of the British Isles; a caution to single ships approaching squadrons or aircraft carriers; warning signals to indicate the presence of submarines; wireless navigational warnings, gale warnings and shipping forecasts for the British Isles; British official wireless messages to merchant ships; a list of storm-signal stations in the British Isles; the lights exhibited by an aircraft at anchor, and the methods by which aircraft should communicate with ships and coast stations.

The order in which this information is given also varies from time to time.

The Supply of Weekly Complete Editions to H.M. Ships. Each ship receives two copies for the use of the navigating officer. One copy is retained in the special guardboards supplied, and the other may be cut up for correcting charts and publications.

A copy of Section IV is supplied in addition for W/T operators. Drifters attached to parent ships are supplied with one complete copy.

Form H.133 is used as a combined supply and receipt note, and before it is signed and returned, the utmost care should be taken to check that the weekly complete editions received are in sequence.

Each *Notice to Mariners* is headed by its number. Then

follows in large capitals the general locality, and in smaller type, a brief summary of the information under appropriate headings.

Underneath the notice is a list of the charts or the publications affected and the authority for the information, followed by the number and date of the notice. Sometimes the list gives both charts and publications.

Admiralty Notices to Mariners (Temporary and Preliminary Notices). These notices are marked (T) or (P) after the number of the notice. In addition to the monthly list of (T) and (P) notices still in force, reprints of all (T) and (P) notices in force on the 31st December is published in the *Weekly Complete Edition* No. 1 of each year.

CORRECTING CHARTS

All small but important corrections affecting navigation that can be made to the charts by hand are promulgated in *Admiralty Notices to Mariners,* and, with the exception of corrections from temporary or preliminary notices, should at once be made neatly in waterproof red ink on the charts affected. The year, if not already shown, and the number of the notices are inserted, also in waterproof red ink, in the bottom left-hand corner of the chart, thus: 1936—407—509—1106—

The recognised abbreviations shown on Admiralty chart 5011 should be used. A copy of this chart is shown at the end of this Volume.

If several charts are affected by a notice, the largest-scale chart should be corrected first.

On Large-Scale Charts always insert the abridged descriptions, as shown on chart 5011, of all details of all lights, light buoys, and fog signals, and the year dates of obstructions, reported shoals, dredged channels, depth of water on bars, etc., and irregularities of lights.

On Coastal Charts insert the abridged descriptions of only the principal lights and fog signals, that is, those lights and signals that will assist in approaching or making the land.

Particulars of such lights should be omitted in the following order as the scale of the chart decreases:

1. height.
2. period.
3. number in group.
4. visibility.

Note. *The colour is never omitted except when the light is white.*

Particulars of fog signals should be inserted in their appropriate positions if there is sufficient space, otherwise they should be entered in a tabulated list in the title or some other convenient place. Inner light buoys and beacons should not be inserted on

coastal charts. Against other light buoys insert only the character of the light.

On Ocean Charts only lights which are visible 15 miles or over should be inserted and detail about them should be confined to character and colour.

Insertion of Writing, etc. If possible, insert writing clear of the water, unless the relative objects are on the water, and take care not to obliterate any information already on the chart. When cautionary or tidal notices, etc., are inserted they should be written in a convenient but conspicuous place, preferably near the title, where they will not interfere with other details.

Erasures. Any details which have to be cancelled, should, when necessary, be crossed through in waterproof red ink. *They should never be erased.*

Blocks. *Notices to Mariners* are occasionally accompanied by reproductions of portions of charts which are called 'blocks', and when correcting charts from such blocks, bear in mind the following points.

1. A block not only shows corrections in red, but may also cancel work already on the chart. The fact that a block accompanies a notice does not mean that the text of the notice can be disregarded.

2. The boundary lines of a block are arranged for convenience of reproduction, and need not be followed when the block is cut for pasting on the chart, if paragraph 1 is considered.

3. The new information shown on a block can sometimes be inserted on the chart by hand; the reason for printing the block in such an event is to avoid a long description of the new information in the text of the notice.

4. If the chart is distorted the block will not always fit the chart exactly; therefore, when a block is pasted on to the chart, care should be taken that the more important navigational corrections fit as closely as possible. This can best be done by fitting the block while it is dry, and making two or three pencil ticks round the edges to use as fitting marks.

Apply paste to the chart and not to the block.

Correcting Charts from Temporary and Preliminary Notices. These corrections should be inserted in pencil on the charts, together with the number of the notice—for example, $\frac{742}{1935}$ (T)—which should also be entered in the bottom left-hand corner of the chart under the small correction notations.

Temporary corrections should be rubbed out when the notice is received cancelling them, but preliminary notices should be inked in when the notice is received reporting that the changes have been made.

Charts in stock at the Admiralty Chart Establishment, chart agencies and depots are not corrected from (T) and (P) notices, and charts received from any of these places should be corrected in pencil as necessary from the copies of such notices already held, or from those supplied with the charts.

Corrections from Wireless Navigational Warnings. These warnings usually concern derelicts and drifting obstructions, the temporary extinction of lights, the displacement of important aids to navigation, ice reports, etc., and they should be noted in pencil on the charts affected. Wireless navigational warnings of a permanent nature and those concerning derelicts and drifting obstructions dangerous to navigation are re-issued as *Admiralty Notices to Mariners* but other warnings are not re-issued in this way, except in special circumstances.

Corrections from Information Received from Authorities other than the Admiralty. This information should be noted in pencil on the charts affected but no charted danger is to be expunged without the direct authority of the Hydrographer. When an *Admiralty Notice to Mariners* is received confirming this information, the pencil corrections should be erased and the necessary corrections should be inserted in the way already described.

ADMIRALTY SAILING DIRECTIONS

Admiralty Sailing Directions, sometimes called '*Pilots*', are published in about 73 volumes. They cover the whole world, and contain general information useful to the navigating officer.

The contents of each volume conform generally to the following sequence.

1. Inside cover. Caution to ships approaching British ports. Details of examination service.
2. Notation form for supplements and summaries of notices relating to the book.
3. Caution against using the book without consulting the latest supplement.
4. Caution regarding the units of measurement and other standards used in the book.
5. Advertisement to the edition. This states the latest information for which the book has been corrected.
6. List of contents.
7. List of views.
8. Information about Admiralty charts and other hydrographical publications, and general navigation.
9. Index chart. This covers the area described in the volume, and shows the charts which, at the date of publication given in the advertisement, make up the area, with the number of the chart marked in the corner of the chart limits. A star and a number against the name of a place—for example, Skegness 93*—shows

that a plan of Skegness is published on chart 93. A number against the name of a place—for example, Port Blyth 1626—shows that a separate plan is published of Port Blyth, bearing that number.

10. Chapter I. Except in those volumes that are concerned with the British Isles, Chapter I opens with a brief description of the countries covered by the volume, their government, flora, fauna, trade and currency. Then follow, in all volumes, details of meteorology—tides—tidal streams—signals—cautions—lifesaving—system of buoys—communications—W/T—dockyards—rat destruction—standard time—fuel supplies—and any directions not given in *Ocean Passages for the World.*

11. Chapter II, etc. Detailed description of the area covered by the volume. The largest-scale charts of the area being described are shown on the bottom line of each page.

12. Appendices. At the end of the book there are several appendices which give details of the following :

(*a*) *Orders in Council* concerning dockyard ports.
(*b*) A list of ports available for underwater repairs, with details of the largest dry dock, floating dock or patent slip at each port.
(*c*) A list of the principal ports, showing particulars of depths, etc.
(*d*) Meteorological tables collected from various places in the volume.
(*e*) A list of places suitable for taking magnetic observations.

13. Detailed index.

Discrepancies. Should information given on charts and in the *Sailing Directions* differ, the information given on the largest-scale chart should be accepted.

New Editions. A new edition of each volume of *Sailing Directions* is published at intervals of approximately 10 to 12 years. The numbers of the *Notices to Mariners* affecting it between the dates of going to press and of issue to ships, are given in the notice announcing its publication to enable the new edition to be corrected before being brought into use.

Supplements. A supplement to each volume is generally published about every 15–18 months, each succeeding supplement cancelling the former one. Details of each supplement received should be entered on the tabular form on the fly leaf of the book. The last notice used in compiling it is stated in the advertisement.

Summaries of Notices to Mariners. When a volume of *Sailing Directions* is taken up for revision, no further supplement to that edition is issued, but subsequent notices affecting it are summarised each year and issued as a separate publication, until the new edition is published. Details should also be entered on the fly leaf as already described.

Correction from Supplements and Summaries. Supplements and summaries should either be retained intact for reference, and stuck inside the cover of the book, notations referring to them being made on the pages affected, or they may be cut up, the slips being pasted in the appropriate places. Whichever is done, the method of correction should be noted in the fly leaf of the volume.

Correction from Notices to Mariners. A copy of each *Notice to Mariners* affecting the *Sailing Directions* should be pasted into them in its appropriate place, after the charts have been corrected. These corrections are not made at the Admiralty Chart Establishment or the chart depots.

ADMIRALTY LIST OF LIGHTS, FOG SIGNALS AND VISUAL TIME SIGNALS

Admiralty Lights Lists are issued in nine parts for the whole World, divided geographically as shown on the index chart at the beginning of all volumes. The contents of each volume are as follows :

1. Caution to ships approaching British ports. Details of the examination service.
2. Index chart, giving the limits of the volumes.
3. Preface.
4. Contents.
5. Introductory remarks. Description of types of lights, fog signals, etc. Regulations for light houses and light vessels, including any distress and special signals they may show.
6. List of Lloyd's signal stations.
7. *Stevenson's Table* for calculating the distance a light should be visible from different heights of eye.

The table is entered with the height of the light, and the height of the observer's eye, and the distance of the horizon from each is extracted. The distance the light should be visible is the sum of these two distances, as explained in Chapter IV on page 67.

8. Details of all navigational lights in the area covered by the volume, *except light buoys*. Details of fog signals, other than W/T. fog signals.

Types of Printing. Different types of printing are used to distinguish various lights as follows :

THICK IONIC LETTERS. Those lights intended for making the coast and the visibilities of lights showing 15 miles or over.

ITALIC CAPITALS. The names of light vessels.

Italics. Light floats.

Ordinary Roman Type. Lights other than the above.

Position. The approximate latitude and longitude are given to facilitate reference to the chart.

Heights. (*a*) The height given in column 6 is measured between the centre of the lantern and the level of mean high water springs.

(*b*) The height given in column 9 is that of the structure, measured from top to base. With light vessels, it is the height of the daymark above the waterline.

Distance. The distance given in column 7 is that at which an observer with a height of eye of 15 feet would be able to see the light in clear weather.

Sections. The true bearing of sectors *from seaward* is given in column 10.

9. Diagram to facilitate the comparison of zone times at different places.
10. Uniform time system in use throughout the world.
11. List of visual time signals.
12. Detailed index.

Correction of Light Lists. The volumes are published at intervals of three years, corrected to the 31st December, and in the intervals, supplements to each volume embodying all corrections to the 31st December are published annually.

A gummed label, drawing attention to the existence of a supplement, is issued with each supplement and should be affixed to the front cover of the relative part. The supplements should not be cut up for the correction of the parts but should be retained intact for reference, notations to the supplements being made on the pages of the *Light Lists.*

Amendments to the *Light Lists* are published weekly in Section III of the *Weekly Complete Edition of Notices to Mariners,* and correction should be made where necessary.

Temporary corrections from temporary or preliminary notices should be made in the parts and supplements in pencil only, but other corrections should be made in red ink or by pasting in slips cut from the notices.

The parts and supplements stocked in the Admiralty Chart Establishment or in chart depots are not kept corrected, and copies received from these sources should be accordingly corrected from the *Weekly Complete Editions* of notices before being brought into use.

THE ADMIRALTY LIST OF WIRELESS SIGNALS

This publication consists of two parts, the information in which is so divided that one part gives all essential details concerning individual stations throughout the World, while the other gives general information relating to the various services carried on by means of wireless. It should be borne in mind that the two volumes are complementary, as will be apparent from the following summary of their contents.

Volume I

(1) Inside cover. Caution to ships approaching British ports. Details of the examination service.

(2) Preface (including explanatory notes).

(3) Bibliography. This states the latest information from which the book has been corrected.

(4) Contents.

(5) Directions for correcting the publication (from the supplement and from the *Weekly Complete Edition of Notices to Mariners*); list of abbreviations and system of indexing.

(6) Alphabetical list of call signals of all W/T stations referred to in the book, followed by a similar list for the R/T (broadcasting) stations therein.

(7) List of coast W/T stations. This is a complete list of all coast W/T stations throughout the world open to public service, including the latitude and longitude of their positions to facilitate reference to charts. Those transmitting weather bulletins and storm signals, navigational warnings, time signals, etc., are included also, so that the location of any station may be obtained from this section. Exception is made for W/T direction-finding stations and of W/T fog signals and beacons, the positions of which are given in the appropriate sections.

(8) W/T direction-finding stations. This is a complete list of all stations which determine the bearings of ships on receipt of suitable signals. These stations may work singly or in groups. Stations working together can determine a ship's actual position by means of intersecting bearings.

(9) W/T fog signals and beacons. This section gives particulars of all stations which transmit characteristic signals in foggy or clear weather (or in both) to enable ships to determine their own positions (normally by means of the ship's direction-finding gear). Sometimes signals are transmitted of such a character that D/F equipment is not necessary.

(10) W/T weather bulletins and storm warnings. This section comprises all services that report and forecast the weather, including international reports suitable for the preparation of synoptic charts.

(11) W/T navigational warnings. All stations transmitting information affecting navigation, including tidal and ice signals, are included in this section.

(12) W/T time signals. This section gives details of all W/T services provided for transmitting time signals from standard clocks at various observatories, etc. These signals are of especial value for checking chronometers that are being used for accurate determinations of longitude.

(13) Particulars of stations associated with the distress services of various countries are included; also stations giving a free service of medical advice or transmitting epidemiological bulletins by W/T.

(14) A list is included of all broadcasting stations transmitting information belonging to any of the preceding categories.

(15) Particulars of the organisation for transmitting wireless messages to merchant ships (as given in *Weekly Complete Edition* No. 1 of *Notices to Mariners* each year).

(16) Index of W/T stations.

Volume II

The contents of this volume are arranged on parallel lines to those in Volume I, but the particulars given comprise general procedure in the various services, including extracts from regulations. The most important features are as given in the following summary.

(1) Chart showing international watch-keeping periods (for ships with less than 3 W/T operators). This is accompanied by explanatory notes in the text.

(2) Direction-finding. Introductory notes—accuracy of bearings—diagram for obtaining convergency—fixing position by W/T directional bearings (with diagram)—conversion table (D/F bearing to Mercator bearing)—regulations.

(3) W/T fog signals and beacons. Introductory notes—use of D/F installations on board ships—use of synchronized W/T and sound signals for determination of distance—co-ordination of services—special types of transmission (W/T beacon at Orfordness, etc.). Charts are included showing areas in which co-ordination between services is in operation, with appropriate particulars.

(4) Weather Bulletins. General remarks—ship—W/T weather reports—meteorological codes—meteorological observation stations —storm warning codes—miscellaneous weather services. A chart is included of meteorological forecast areas for the British Isles.

(5) Navigational warnings. Introductory notes—regulations—North Atlantic International Ice Patrol—ice signals (from shore stations and ice breakers), including codes.

(6) Time signals. Diagram to facilitate the comparison of zone times at different places—uniform time system in use throughout the world—methods of transmission of time signals by W/T.

(7) Distress procedure. Great Britain—accidents to H.M. ships and naval aircraft—Western Mediterranean (aircraft distress code)—other special regulations.

(8) Medical advice (transmission to ships at sea). General particulars of services.

(9) Quarantine reports from ships. Use of *International Code of Signals*—lists of ports receiving W/T quarantine reports.

(10) Appendices:

- (*a*) British official wireless messages to merchant ships including a chart of the World showing the areas affected by this organisation.
- (*b*) International Telecommunication Convention, Madrid, 1932 and extracts from the *General Radiocommunication Regulations*.

(*c*) Regulations for the use of wireless telegraphy and telephony by shipping in territorial waters and harbours.
(*d*) International morse code and conventional signals.
(*e*) List of abbreviations to be used in W/T transmission.
(*f*) Tables : (i) Corrections to chronometer time corresponding to rhythmic signals (Modified system).
(ii) Temperature conversion tables.
(iii) Rainfall (Conversion of inches to millimetres).
(iv) Barometer conversion tables.
(v) Wind velocity conversion table (Miles per hour to metres per second).
(vi) Wave length and frequency conversion table.

(11) Detailed index.

Supplements. Each volume is corrected to the 31st December, a new edition of Volume I being published annually. Volume II is republished at longer intervals, as a new edition becomes necessary. A supplement to each volume is published annually.

Volume I. The supplement which is issued simultaneously with Volume I, contains amendments from the 31st December, which is the date to which the book is corrected, up to about four weeks prior to its publication. Subsequent corrections are issued in Section IV of the *Weekly Complete Edition of Notices to Mariners*, and until the actual time of publication affect both old and new editions.

Volume II. The supplement embodies all corrections issued up to the end of the previous year, each succeeding supplement cancelling the former.

Corrections to the *Admiralty List of Wireless Signals* are published in Section IV of the *Weekly Complete Edition of Notices to Mariners.* Important corrections also appear in Section II of these notices.

Copies of the book kept at the Admiralty Chart Establishment and chart depots are not kept corrected.

Two copies of each volume are supplied to ships—one for the navigating officer and one for the W/T operators.

THE NAVIGATIONAL DATA BOOK

(K.R. & A.I. Article 1206)

The object of this book is to provide a continuous record of the behaviour of the ship, and it should contain the following information:

1. the ship's dimensions.
2. revolution tables for various periods from the time of last docking.
3. turning data.
4. points about handling the ship.
5. remarks on the effect of wind and seas.
6. copies of Form S374 with remarks on any changes in the position of the correctors.
7. curves showing the percentage error of the various logs.

Every sea passage should be analysed on its conclusion and all points of interest entered in the book.

The book is to be produced at inspections and is to be transferred to successive navigating officers.

When a ship pays off, the book is to be given to the Admiral Superintendent of the dockyard for custody until the ship recommissions.

DISTANCE TABLES

Admiralty Distance Tables are published in five volumes covering the World and give the shortest navigable distances, in nautical miles, between various ports.

Each volume is divided into sections as shown on the *key chart* in the pocket of the back page.

Any two contiguous sections or volumes have a port common to both, which is marked in red on the key chart.

This common point must be used as a stepping stone when the distance is found between places in contiguous sections.

Example. To Find the Distance from Devonport to Cromarty

Distance Tables Volume I will be required.

Take out the Key Chart, and it will be found that Devonport lies in Section A and Invergordon lies in Section C.

The common port between Sections A and C will be found to be Dover.

From the index, Dover appears on pages 8 and 51.

From page 8,	Dover to Plymouth	= 226′
,, ,, 51,	Dover to Cromarty	= 505′
∴	Plymouth to Cromarty	731′

COMPASS COMPARISON BOOK

This book enables the officer of the watch to keep a course record and to check the compasses. It is divided into columns as follows:

Time	True Course	Pelorus error	Variation	Deviation	Compass Comparisons Ship's Head by							Remarks and signature of O.O.W at the end of each watch.
					Standard Compass	No. 1 Master	No. 2 Master	Pelorus on No.	Steering on No.	Starboard Wing on No.	Port Wing on No.	

SOUNDING BOOK

Whenever soundings are taken, with or without chemical tubes, they should be recorded in this book. It is divided into columns as follows:

Time	Speed by Revolutions	Speed by Log or Log Reading	Amount of wire out	Depth by Tube	Corrected Depth	Depth by Echo Sounding	Nature of Bottom	Remarks

THE DECK LOG

(K.R. & A.I. Articles 863–1208)

A specimen log for a short sea-passage is given opposite this page. Full instructions for writing up the deck log are given in the front of the book together with various meteorological tables.

NOTE. 1. The 'distance run' should be the officer of the watch's estimation of the distance the ship has run through the water in each hour. He should take into consideration:

(*a*) the revolutions.
(*b*) the reading of the log.
(*c*) the state of the ship's bottom.
(*d*) any favourable or adverse weather.

2. With a mercurial barometer, the corrected reading should be logged. With an aneroid barometer, the reading should be corrected from the table in the deck log or in Chapter XIII, and the corrected reading logged.

3. Anchor bearings should be the bearings of shore marks from the position of the anchor.

THE SHIP'S LOG

(K.R. & A.I. Articles 863—1088—1208—1209)

This log should be written up daily from the deck log by the navigating officer. It is inspected and signed by the Captain once a week and sent at the end of each month to the senior officer of the squadron who will forward it to the Royal Victoria Yard.

HYDROGRAPHIC NOTE

Form S.378 K.R. & A.I. Article 1200

This form is supplied to all H.M. ships to enable officers to report any information relating to charts and hydrographical publications.

When information is forwarded, the form should be made out in duplicate.

One copy should be forwarded direct to the Hydrographer.

One copy should be forwarded direct to the Commander-in-Chief of the station.

In each ship, the hydrographic notes forwarded are numbered consecutively, starting at the 1st January each year.

Hydrographic notes should be made out in accordance with the following instructions and *every opportunity should be taken to obtain useful information.*

HYDROGRAPHIC REPORTS BY NAVIGATING OFFICERS

The attention of officers is drawn to the necessity of forwarding to the Hydrographer of the Navy, on all occasions, any information that may be valuable for the correction of the charts and other publications of the Hydrographic Department, in accordance with K.R. and A.I. Article 1200.

Urgent information should be forwarded immediately by W/T or L/T and confirmed by Hydrographic Note (Form S.378) as soon as possible.

The *Remark Book* (Form S.380) formerly supplied for navigating officers was abolished in 1936. In future commanding officers of ships employed on special service such as trooping and making lengthy passages to distant stations, or ships diverted when on such stations for cruises to places seldom visited, will be required to include with their *Letters of Proceedings*, K.R. and A.I. Article 1132, a hydrographical report in which all information of interest to the Hydrographer of the Navy is to be included, except items which have already been reported by *Hydrographic Note* (Form S.378).

Officers rendering these reports should be guided by the following instructions given in K.R. and A.I. Articles 1171, 1172, 1187, 1200, 1205, 1210 (2) and (3), 1213 and 1220 (*a*) and (*b*) in addition to the article cited above.

The Admiralty charts, *Sailing Directions* and other publications should be compared constantly with conditions found actually to exist.

Information, to be of value, must be precise and up-to-date. The date of the information should invariably be given.

The amount of useful information which can be supplied will be, in general, greatest when ships visit unfrequented places, and confirmation of matter already appearing in the *Sailing Directions* is very acceptable.

The volume and page of the *Sailing Direction* affected must always be given, not only when some correction is made to a passage in the book, but also when information is entirely new and cannot be placed under any heading appearing on the page.

The number of the largest-scale chart affected should be always quoted. When any chart is specifically mentioned in the report, the date of the last *New Edition* or *Large Correction* is to be stated, together with the date or number of the last *Small Correction*, as shown on the copy used.

Courses and bearings are invariably to be given as true, measured in degrees (clockwise) from 000° (North) to 360°.

When photographs, sketches, tracings, etc., are sent in, they should be included as enclosures. (See also the sections on *Sketches* and *Photographs*.)

Reports should be forwarded on separate sheets and arranged so that the subject matter proper to each of the numbered sections can be used separately.

It should be remembered that when information is supplied which leads to the correction of an Admiralty chart or plan of a place in foreign waters for which a recognised hydrographic authority exists, credit will not be given in the title of that chart or plan to the ship or officer supplying the information, as reference to the national authority concerned is always made before chart action is taken.

Since the value of the material supplied will depend principally on the extent to which it can be used for the improvement of hydrographic publications, officers should take care that all objects quoted in fixing positions or for other purposes of reference are recognisable with exactness upon the chart.

When dredging operations, or building work such as that of breakwaters, wharves, docks and reclamations is described, a clear distinction should be made between work completed, work in progress and work projected. An approximate date of the completion of unfinished or projected work is valuable.

Information not Required. It may be assumed that the Hydrographic Department of the Admiralty is in possession of complete sets of the latest editions of charts and *Sailing Directions* issued by foreign countries. Tracings of foreign charts therefore are not required.

Information about navigational aids in foreign waters is not usually accepted without prior reference to the Hydrographic Office of the country concerned, as these offices can generally be relied upon to publish notification of all changes of any navigational interest in their own *Notices to Mariners*, copies of which are received by the Hydrographic Department of the Admiralty.

Confirmation of published reports of irregularities in W/T signals is not required.

INFORMATION FOR CHARTS AND SAILING DIRECTIONS

Newly-Discovered Dangers. The position and extent of any shoal or danger discovered, especially of one upon which a vessel has struck or grounded, should be determined, if practicable, by five horizontal sextant angles between well-selected objects; a careful true bearing to one of these objects should be given. The least depth should be obtained whenever possible and, if there is shoal water, the nature of the bottom. (See K.R. and A.I. Article 1171.)

Soundings. When soundings are recorded, the method of sounding, whether hand-lead, machine, or echo, and whether tubes are used, is always to be stated, together with the dates and times, and the reductions used.

Soundings are to be reduced to the level of the datum of the Admiralty chart, or, when this is not known, to a level such that the tide will seldom fall below it. (See also remarks under *Tides*.)

Harbour Works and Port Information. When reference is made to piers or wharves, the depths at the outer end and alongside are the most important items of information that can be given, although all dimensions are useful.

The length and bearing of any extensions should be given in such a way that it can be plotted on the chart, if the scale permits, with precision: the position of any new lights on it should be stated exactly, and the removal or continuance of any lights charted on the pier or breakwater before extension should be mentioned.

Information in Admiralty publications on matters such as docks, cranes, patent slips, facilities for repairs, supplies of coal, oil, water and stores, time, weather, tidal signals and pilots, should be checked for additions or corrections.

Where dredged channels exist, the date of the last dredging and the depth obtained should be noted.

Local Publications. Many ports, even those of secondary importance and in distant parts, publish a guide book compiled by the local authorities, and these books frequently contain a plan of the harbour. Opportunity should be taken, when circumstances permit, of comparing the information in such publications with that given in the *Sailing Directions* and on charts and of including a copy with the report, if the contents appear to contain useful material not already given in the publications of the Hydrographic Department. Care should be taken to obtain the date and authenticity of the material in the book, if these are not given. On the charts or plans in these books, it is important to note whether the datum for heights and soundings, the scale and the true north are given and to check them or to supply them if they are absent.

A port officer sometimes has a large-scale manuscript plan of the harbour and approaches which is merely his own enlargement of the plan published by the government. The value of such a plan, however, can be judged only by comparison with the Admiralty chart.

Town plans are not generally of importance, but these should be considered for forwarding if the chart is shown by them to need amendment for water-frontage or other matter of navigational interest.

Conspicuous Objects. Objects which are already noted on the

chart or described in the *Sailing Directions* as conspicuous, should always be observed for any changes in them that may have occurred, and the growth or erection of anything that may obscure them, or detract from their value as marks, should be noted. It should be remembered that in many parts of the World charts are still based on surveys made a considerable time ago and that conspicuous objects are particularly liable to change.

Any conspicuous objects, not at present shown on charts, that are of navigational interest should be described as fully as possible for shape, colour and size, and their exact positions given with reference to objects that are shown on the chart.

Tracks. When tracks are described or inserted on copies of charts, their value is greatly enhanced if they are accompanied by soundings or by a note of the observed least depth, reduced to chart datum.

Channels and Passages. When reports are made on a discrepancy in the charting of a channel, or a passage between islands, and when information is supplied about one shore only of a strait, or about some island in such waters, every effort should be made to obtain a connexion by angle or bearing between the two shores. The absence of such a connexion may have been the original cause of the discrepancy reported, or it may cause serious difficulty in making proper use of the information supplied.

Positions. Observations for positions of little known places are always welcomed, especially if the officer has reason to question the charted position. Full details of astronomical observations should be given in order that their value may be assessed. When practicable, the position should be linked up with some existing triangulation or known position, and care should be taken to dispel uncertainty about the existence, extent, and precise position of reported dangers and doubtful islands, and to obtain the least depth where appropriate. Careful examination of such objects is of the greatest importance both to the general interests of navigation and to the maintenance of the reputation of the Admiralty charts for accuracy and completeness of information.

Whenever a search or examination is made, the state of the weather and light should be described fully if they are likely to have had any influence on the result.

It cannot be emphasised too strongly that, in general, the only effective method of obtaining evidence about the existence of these vigias is to take positive soundings in the vicinity and, if possible, to obtain specimens of the bottom.

Orthography. In some places, for example, certain atolls in the Pacific Oceans, it has been found that the native names reported as the names of islands are in reality only the names of localities on those islands and that each island has either a different name or no general name at all. Officers should take every

precaution to ascertain the precise local significance of any new native names that are reported. Great care should be taken to obtain the correct rendering of native names.

Information concerning Lights. If lights are observed to have characteristics different from those described in the *Admiralty Lists of Lights*, as amended by latest *Notices to Mariners*, every endeavour should be made locally to ascertain whether the alterations are permanent. (See K.R. and A.I. Article 1205.)

Information concerning Tides and Currents. Full instructions for obtaining this information are given in the *Admiralty Manual of Hydrographical Surveying*.

Tidal Streams. Observations of tidal streams should be obtained whenever possible. If only a general description can be given, care must be taken to avoid any ambiguity that might arise from the use of the terms 'flood' and 'ebb' streams. It is generally preferable to give the direction of the stream, that is, 'east-going' or 'west-going'. The time of the change of stream should always be referred to high water; for instance, 'the north-going stream begins two hours after high water'. When the time of local high water is not known, the turn of the stream should be referred to high water at the nearest port for which predictions are given in the *Tide Tables*.

Currents. In order that full value may be obtained from information on currents, it is essential that the ship's position should be checked by observations as frequently as is practicable, because the currents experienced during the course of, for example, a period of twenty-four hours, may vary considerably both in direction and in strength. Whatever the interval between sights may have been, the results, when used by the Meteorological Office, are converted to twenty-four hour values and are plotted in a mean position between the observed positions. Should the vessel have altered course between sights, a considerable error may be introduced by assuming that this mean position lies mid-way between the observed positions. It is necessary therefore that this mean position should always be obtained by estimation for half the time that has elapsed between sights.

If the following details are available they should invariably be included.

1. Date.
2. Positions between which current was experienced.
3. Mean position between observations.
4. Time elapsed between observations.
5. Direction (True).
6. Speed (Knots).
7. Direction and force of the wind.

Information concerning Magnetic Variation. The accuracy of the lines of magnetic variation shown on the Admiralty charts

is important not only for the ordinary purposes of navigation, but also for the finding of the secular change of variation, and such accuracy can only be secured if a sufficient number of observations is forthcoming. Every opportunity should be taken, therefore, to obtain observations at sea for magnetic variation, especially in those localities where the variation changes appreciably with a small change of position. (See K.R. and A.I. Article 1187.)

Information concerning Wireless Services. Reports of any irregularities in W/T signals that have not been announced should be made. Any other information that may be useful for the *Admiralty List of Wireless Signals* should be forwarded.

If W/T fog signals or beacons are observed to have characteristics differing from those given in the *Admiralty List of Wireless Signals*, as amended by the latest *Notice to Mariners*, endeavour should be made locally to ascertain whether these alterations are permanent.

Similarly, any changes observed in the time of transmission of weather bulletins and storm warnings, navigational warnings or time signals, should be verified as being permanent.

Meteorological Information. Descriptions of any unusual weather experienced are always of value to the Meteorological Office, particularly observations of hurricanes and other revolving storms. The movements of the upper clouds during the approach of a revolving storm—that is, for a period of three days or so before it reaches the locality of the observer—are of considerable interest and may give valuable indications to the Meteorological Office. When any meteorological phenomenon is being reported, it is important to give details as fully as possible of all the conditions prevailing at the time.

Zone Time. Information concerning the time kept locally, if different from that given on the latest edition of the Time Zone Chart (No. 5006) or in the most recently published *Light List*, whichever is the more recent, should be supplied.

Original Surveys. Officers who may undertake any original survey which may be used either for the production of a new plan or the correction of an existing plan or chart, should refer to the *Admiralty Manual of Hydrographical Surveying* and to the *Admiralty Manual of Tides*.

Sketches and Photographs. Illustrations derived from sketches and photographs form a very valuable adjunct to the *Sailing Directions*, and every opportunity should be taken of adding to them. The existing views in the *Sailing Directions* or on charts should be examined for possible improvements—for example, the addition of a conspicuous object.

Usually, a good sketch will be of more value to the mariner than a photograph.

Sketches and photographs of navigational interest may be divided broadly into three classes :

1. General views of a coast or anchorage, showing the principal charted features and thus enabling the mariner, when making land or approaching the anchorage, to identify these features more readily than can be done from a written description.

2. Views of leading marks or anchoring marks.

3. Sketches or photographs of special objects that cannot easily be described in words.

In the circumstances attending 1, and normally 2 also, a photograph will have to be taken from a considerable distance and will usually give poor results, for the purpose in view, unless enlarged or taken with a telephoto lens.

Even when enlarged, the photograph, as a rule, will require touching up in order to bring out or to emphasise the desired conspicuous features, and this can be done satisfactorily only by the man on the spot, either when in a similar position on a subsequent occasion or from an outline sketch made at the same time as that on which the photograph was taken. Alternatively, a photograph may be used for the purpose of improving or correcting a sketch.

If an outline sketch is made in order to supplement a photograph, the names or descriptions of the conspicuous objects shown on it can conveniently be inserted against them, and it can then be attached to the photograph.

Some useful hints for sketching distant objects are given in *Hydrographical Surveying* by Wharton and Field, pages 93–95. The most important point is that the vertical scale should be larger than the horizontal, that is, the heights of objects should be exaggerated somewhat; but this should be done with discretion, especially if there are any objects, such as islets, in the foreground.

When no outline sketch has been made, the names can be inserted on the photograph itself, but when this is done a second print, without names, should be attached.

Always state in the report and on the photograph or sketch itself, the exact position from which the photograph was taken or the sketch made.

Sketches and photographs forwarded with a view to reproduction should never be gummed or pasted to the pages of a report, but should be placed in an envelope which should be attached securely to the report.

CHAPTER III

THE SHIP'S TRACK

It is necessary to begin plotting the ship's track from a known position. If this position has been found by the intersection of two or m... ...sition lines, it is marked with a small circle and called...

...sition lines were obtained by observations of ter...

...*ition*, if the position lines were obtained by reli... ...venly bodies, and indicated by the abbreviation...

The... ...n which the ship is known to be at any given time is therefore shown on the chart thus :

⊙*Fix* 1100 or ⊙*Obs.* 1100

NOTE. Position lines are fully explained in Chapter IV.

To Plot a Point Described by its Latitude and Longitude. When a point is described by its latitude and longitude, its position is laid down on the chart by one of the following methods.

1. Place an edge of the parallel rulers along a parallel of latitude and move them until one edge passes through the latitude of the place as indicated on one side of the chart. With the dividers, measure the length at the top or bottom of the chart from the nearest meridian to the required longitude, and lay this off from the same meridian along the parallel of latitude shown by the rulers. If more convenient, the rulers can be placed to the longitude, and the latitude then set off with the dividers.

2. Having placed an edge of the parallel rulers to the given latitude, draw a short line in the neighbourhood of the given longitude ; by the same method draw another short line parallel to the meridian corresponding to the given longitude. Where these two intersect is the required position.

The latitude of any point is taken off in a similar way, either by using the dividers to measure the distance of the point from the nearest parallel, and transferring the dividers to the side ; or by referring it to the side by means of the parallel rulers. The longitude is found in the same way.

When a position is transferred from one chart to another, the bearing and distance of some object common to both charts should be used as a check in addition to the latitude and longitude.

PLOTTING THE SHIP'S TRACK

Plotting the ship's track from a known position is carried out in two steps.

1. By plotting the course steered and the speed made good through the water, thus arriving at a position called the *dead reckoning position.*

2. By plotting on from the dead reckoning position the effect of:

(*a*) current.

(*b*) tidal stream.

(*c*) wind, other than that already allowed for in the speed made good through the water.

The position now arrived at is called the *estimated position.*

Before the actual plotting on the chart can be described it is necessary to consider these various factors.

Current. Information concerning currents is given on Admiralty charts and special current charts as described in Chapter XV. They must not be confused with tidal streams.

Tidal Streams. Information concerning tidal streams is given on Admiralty charts and special tidal atlases. They can also be calculated from the *Tide Tables* by the methods described in Chapter XII. The direction of a tidal stream or current is always given as the *true* direction towards which it is running, and is usually called the *set*; thus a tidal stream is said to be setting 260°.

Wind. The effect of wind will vary with every type of ship, and it is most necessary that the navigator should collect as much information as possible concerning the behaviour of his particular ship with various wind forces in various relative directions. These data should be noted in the *Navigational Data Book.*

The wind affects a ship in two ways:

1. The action of the wind on the hull and superstructure which tends:

(*a*) to increase or decrease her speed made good through the water. This effect is allowed for in the dead reckoning, as already described.

(*b*) to blow the ship to leeward. This effect is frequently countered by the ship's tendency to turn up to windward. With an inexperienced or careless helmsman the mean course steered may be 2 to 3 degrees to windward of the course ordered. If this occurs, the effect may be more than counteracted, and it is possible that the course made good may be to windward of the course it is desired to steer. This is particularly noticeable in light craft running with the wind and sea on the quarter and is known as 'boring to windward'.

This effect can be gauged in two ways:

(i) by noting the direction of the ship's head every 2 or 3 minutes over a period of half an hour or more and thus obtaining a mean course steered.

(ii) by comparing the track kept by an accurate automatic plotting instrument, with the course that the helmsman has been ordered to steer.

2. The drift of the surface water caused by the wind. This factor can be estimated only by experience and a knowledge of the meteorological conditions in the past forty-eight hours in the area through which the ship is steaming.

A good rule for this estimation is that the surface drift is usually found to amount to about 1/50th of the wind velocity and, in temperate latitudes, is inclined at about 40 degrees to the direction towards which the wind is blowing, to the right in the northern hemisphere, to the left in the southern hemisphere.

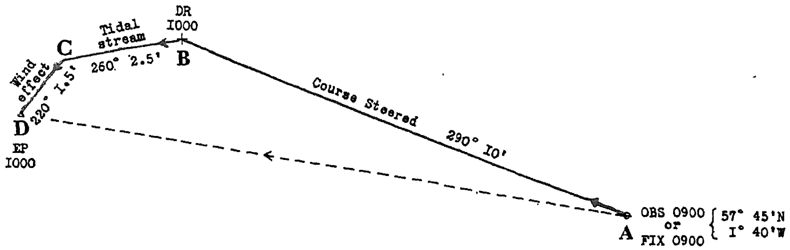


FIGURE 14.

An example will illustrate how these factors are allowed for when the track is plotted.

Suppose that at 0900, the ship is known to be in latitude 57° 45′ N. longitude 1° 40′ W., steering a course 290° and making good a speed of 10 knots through the water. From the tidal stream atlas it is found that the tidal stream should be setting 260° at a rate of 2·5 knots. The wind is N.E., force 8.

1st Step. Plotting the Course Steered and the Speed made Good through the Water.

In figure 14, the starting point A may be a fix or an observed position, or the latitude and longitude may be given, in which event it is plotted on the chart in the manner already described.

Place the parallel rulers on the nearest engraved compass rose so as to pass through the centre and 290°, the course being steered, and also note, for increased accuracy, that it passes through (290°—180°), that is, 110°. Transfer this direction so as to pass through the starting point A and draw a line of sufficient length to show the whole run; this will be the ship's course. The patent log or revolution table will give the distance steamed through the

water between 0900 and 1000. In this example the speed made good is ten knots. Measure off 10 miles from the scale of latitude corresponding to the latitude of A and lay it off from A along the course, thus obtaining the point B which is called the *dead reckoning position*.

Mark this point with a small cross and notation, thus :

+D.R. 1000

If a magnetic compass is used, the compass course must be corrected for deviation and laid off from the magnetic compass rose, allowance being made for the alteration of variation since the year for which it is given on the charts, as explained in Chapter I.

NOTE. (*a*) An automatic plotting machine, worked from a reliable compass and a reliable patent log, will keep the ship's dead reckoning position.

(*b*) The dead reckoning position, being concerned with the speed made good through the water, will allow for the amount that the ship's speed is reduced or increased by the action of :

(i) a head sea or sea astern.

(ii) the effect on the ship's hull of a wind ahead or a wind astern.

2nd Step. Plotting on, from the Dead Reckoning Position, the Effect of any Current, Tidal Stream, or Wind Effect (other than that already allowed for in the speed made good through the water).

It is now necessary to consider the tidal stream which is setting 260° at 2·5 knots and the effect of the wind which is N.E. force 8.

It is estimated, either from data obtained from the *Navigational Data Book* or by calculation from the above-mentioned rule, that the effect on the hull, and the effect of the surface drift of the water, will set the ship in a 220° direction at 1·5 knots.

From the 1000 D.R. position, B, lay off a line BC, 260°, 2·5 miles. This represents the amount the ship will be set by the tidal stream.

From C lay off a line CD, 220°, 1·5 miles. This represents the amount the ship will be set by the wind.

NOTE. The loss or gain of speed through the water caused by the wind has been allowed for in the dead reckoning, as already explained.

The point D is called the *estimated position* and is marked with a small triangle, thus :

△ E.P. 1000

The dotted line AD is the actual track which the ship will make good over the ground, and when the course to steer is worked out in advance, this track must be drawn on the chart to ensure that the ship does not get too close to any dangers.

The estimated position can be defined as the best estimate of the ship's position worked up from the last fix, or reliable observed position, by allowing for every known factor that may have affected her movements.

It cannot be too strongly emphasised that although certain checks such as soundings, doubtful sights, or a single position line

as described later in this Volume, may tend to cast doubt upon the accuracy of the estimated position and may quite properly lead to the adoption of some more probable position, until a definite fix or a reliable observed position is obtained, *the estimated position should not be discarded or entirely neglected.*

SUMMARY OF POSITIONS ON THE CHART

A Fix is the ship's position found from reliable observations of terrestrial objects, as explained in Chapters IV and V.

The Observed Position is the ship's position found from reliable sights of heavenly bodies as explained in Appendices II and III at the end of this Volume.

The Dead Reckoning Position is the ship's position obtained by plotting on from the last fix, or reliable observed position, the speed made good through the water along the course steered by compass.

The Estimated Position is the best estimate of the ship's position worked up from the last fix, or reliable observed position, and is found by allowing for every known factor that may have affected her movements.

TAKING COURSES FROM THE CHART

The course from one place to another on the chart is taken off by placing an edge of the parallel rulers so as to pass through the two places, and then moving the rulers to the nearest compass rose ; the compass rose can be read off, either true or magnetic. It is a good plan to note the reciprocal reading of the compass rose as this will indicate if there is any distortion.

If a magnetic course is required, allowance must be made for the change of variation, as explained in Chapter I.

Courses and bearings should always be laid off from the compass rose nearest the ship's position. It is important to notice how the variation changes in different areas on the charts.

TO SHAPE A COURSE ALLOWING FOR A TIDAL STREAM

Example. What course must a ship steer when steaming at 12 knots to make good a course 090°, if it is estimated that the tidal stream is setting 040° at 3 knots ?

Lay off the course to be made good, AB in figure 15. From A lay off the direction of the tidal stream, AC. Along AC mark off the distance the tidal stream runs in any convenient interval on a chosen scale. In figure 15 a one-hour interval has been allowed; thus the tidal stream will run 3 miles, AD.

With centre D and radius the distance the ship runs in the

same interval, and on the same scale, cut AB at E. Then DE is the course to steer.

This course is actually steered from A. The distance AE is the *speed made good* in an 090° direction and is usually marked with two arrow heads.

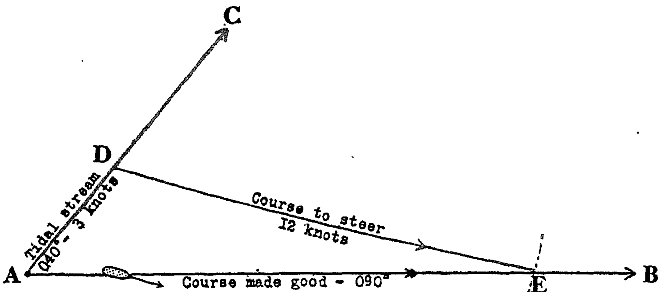


FIGURE 15.

TO REACH A POSITION AT A DEFINITE TIME ALLOWING FOR A TIDAL STREAM

Example. What course must a ship steer, and at what speed must she steam, to proceed from a position A to an anchorage B in $1\frac{1}{2}$ hours, allowing for a tidal stream setting 150° at 3 knots ?

Join AB as shown in figure 16. This determines the course and distance to be made good in $1\frac{1}{2}$ hours : 090°, 15 miles.

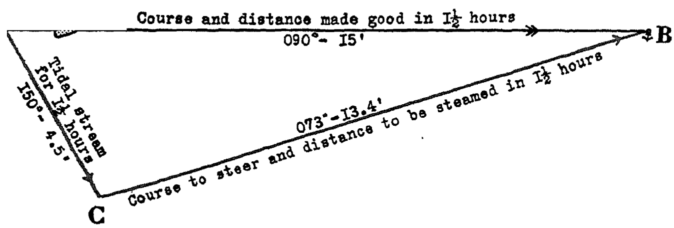


FIGURE 16.

From A lay off the direction of the tidal stream, 150°, and the distance it runs in $1\frac{1}{2}$ hours, AC=$4\frac{1}{2}$ miles. Join CB.

Then CB, the course to steer, is 073°, and the distance the ship, must steam in $1\frac{1}{2}$ hours=13′·4. The speed of the ship, therefore, is 8·9 knots.

TO KEEP THE DEAD RECKONING OR PLOT DURING MANŒUVRES

When the fleet is manœuvring, alterations of course are frequently so numerous, and the distance run on each course is so short, that the curves described by the ship while making the various turns form a large portion of the plot, and it is therefore essential that

allowance should be made for the turning circle and the loss of speed while turning, if the reckoning is to be accurate.

At any time it may be necessary for a ship engaged in manœuvres to shape a course for a particular position, so it is essential that the reckoning should be kept in such a way that the position of the ship at any moment may be plotted on the chart with the least possible delay.

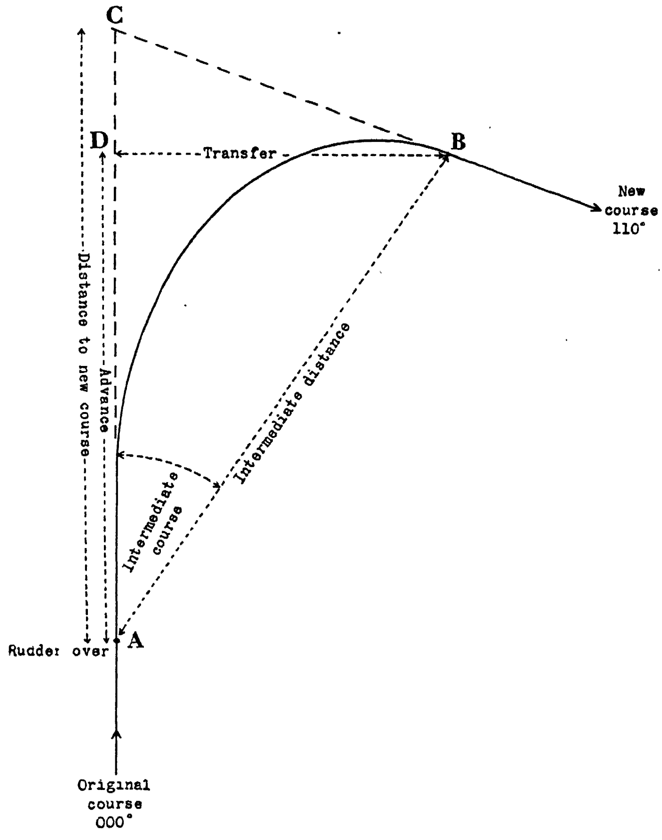


FIGURE 17.

NOTE. When ships form part of a squadron within easy visual touch of the flagship, and are unlikely to be detached during the manœuvres, it is advisable that they should plot the flagship's track for the following reasons :

1. The flagship's less frequent alterations of course and steadier speeds reduce the chance of errors.
2. The times recorded in the signal log give a valuable check on the times taken for the plot.
3. If the ship is detached unexpectedly, a range and bearing of the flagship will at once give the ship's position.
4. The alterations of course can often be plotted before it is necessary for the navigating officer to devote his attention solely to the handling of his own ship.

Before the various methods of allowing for the turning circle are considered, it is necessary to define the terms which will be used.

In figure 17 a ship steering 000° puts the wheel over at the point A to alter course to 110°, and is steady on the new course 110° at point B.

Intermediate Course and Distance is the angle and distance from the point where the wheel was put over to the point where the ship is steady on her new course.

Angle CAB=the intermediate course.
AB=the intermediate distance.

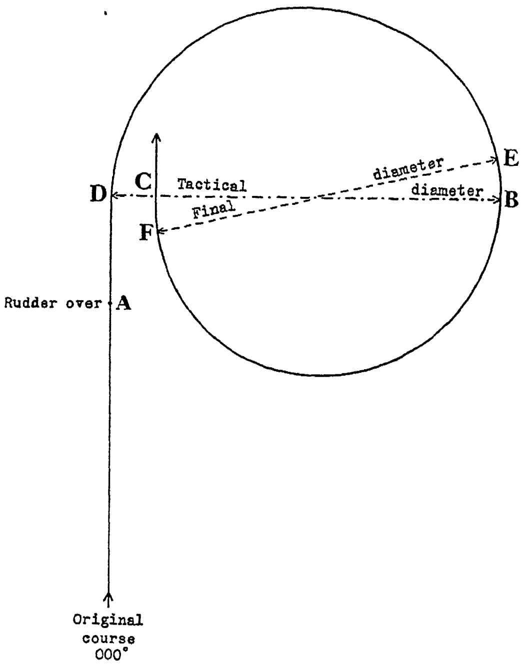


FIGURE 18.

Distance to New Course is the distance from the point where the wheel was put over to the point of intersection of the new and original courses.

AC=the distance to new course.

Advance is the distance that the centre of gravity of a ship has advanced in the direction of the original course measured from the point where the wheel was put over.

AD=the advance.

Transfer is the distance that the centre of gravity of a ship is transferred in a direction at right angles to the original course.

DB=the transfer.

In figure 18, a ship steering 000° alters course to starboard

and turns 360°. The wheel is put over at the point A; the ship has turned 180° on reaching point B and 360° on reaching the point C.

Tactical Diameter is the perpendicular distance between the ship's original course and her position when she has turned 180°.

BD = the tactical diameter.

Final Diameter is the diameter of the circular path which a ship traverses if the wheel is kept over, when the path becomes practically a circle.

EF = the approximate final diameter.

Length of the Arc is the distance from point to point along the path actually described by the ship when turning.

All the above data for a ship can be obtained from the turning trials.

METHODS OF KEEPING THE ACCURATE DEAD RECKONING ON A LARGE SCALE

There are various methods of allowing for the turning circle, all of which involve plotting.

1. *Plotting instruments.*
2. *Intermediate course and distance.*
3. *Distance to new course.*
4. *Drawing the turning circle with compasses.*
5. *Mid-time of turn.*
6. *Advance and transfer.*
7. *Using a protractor cut to represent the turning circle.*

1. **Plotting Instruments.** There are two types of plotting instruments:

(*a*) the Brewerton course recorder.
(*b*) the Mark V course recorder.

Most of H.M. ships are supplied with one or more of these instruments, which are described in Chapter VIII.

2. **Intermediate Course and Distance.** If a ship X, in figure 19, steams a course 000° and puts her wheel over to alter course to 110° when in position A at 0900, she will follow the curve ADB and will be steady on her new course, 110°, at the point B.

With data obtained from the turning trials, the point B can be plotted and the time taken to travel from A to B along the arc can be found.

During the turn from A to B the ship will lose speed, and when steady on the new course she will not be moving at her original speed, so it will not be correct to continue plotting from the point B unless some allowance is made for this loss of speed.

For heavy ships, the distance traversed in regaining each knot of speed lost can be taken as 100 yards.

Suppose that the ship X, in figure 19, with an original speed of 15 knots at A, loses four knots on the turn and is moving at 11 knots when she steadies on the new course at B. She will, therefore, have to regain 4 knots, and in doing so will have to cover $(4 \times 100) = 400$ yards.

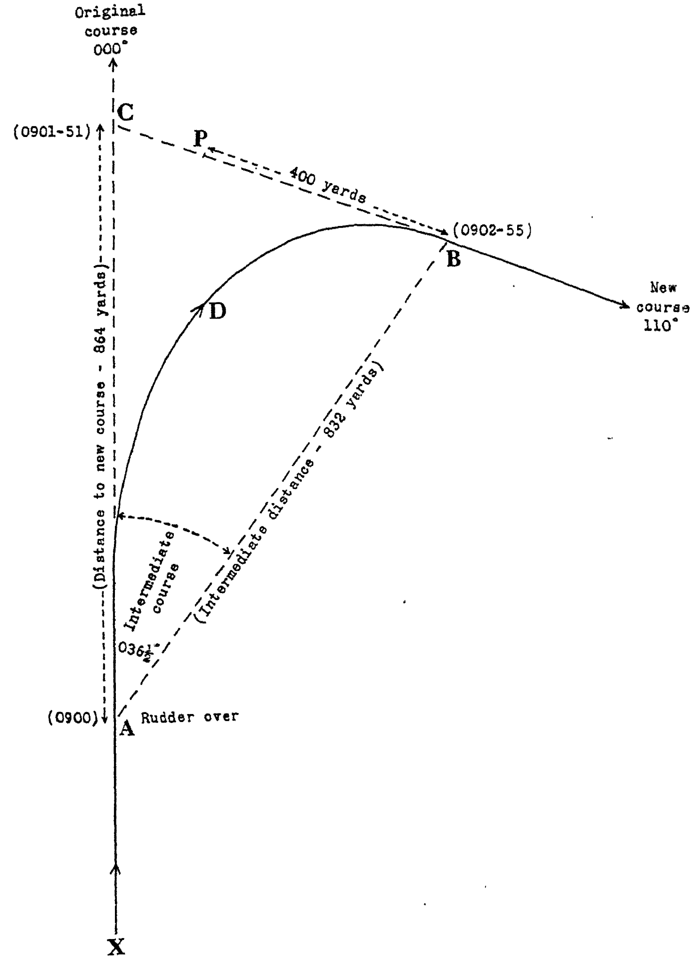


FIGURE 19.

Instead of being plotted at B at the end of the turn, she could, therefore, be plotted at P, where BP is 400 yards, and 15 knots speed will be allowed from this point.

It is more convenient, however, to make this allowance by a time correction.

The time taken to turn is known, and it would be correct to place this time against the point P; but, since the point B is actually plotted, it is more convenient to place a time against the

point B, which will be the time taken to turn plus the time taken to steam the distance PB at the original speed.

This is known as the *Time Correction* and, if added to the time of putting the wheel over, gives the time from which the ship can be plotted on from B at the original speed.

All subsequent positions can now be laid off along the new course and worked from the point B, the time interval being calculated from the corrected time.

From the results of turning trials of any ship, tables can be constructed giving the intermediate course and distance for any alteration of course, for varying speeds and rudder angles.

The following is an example of such a table constructed for a battleship, speed 15 knots, using 15° of rudder :

Amount of Alteration.	Intermediate Course.	Intermediate Distance.		Time Correction.	
Degrees.	*Degrees.*	*Yards.*	*Miles.*	*m.*	*s.*
20	2	285	0·14	0	47
40	11	510	0·25	1	20
60	17	625	0·31	1	46
80	25	730	0·36	2	12
100	32	800	0·40	2	40
120	41	865	0·43	3	10
140	50	900	0·45	3	40
160	58	895	0·45	4	13
180	67	870	0·43	4	53

If the table in the above example is used, the point B is plotted 036½°—832 yards from A, and the time correction for the turn is 2 minutes 55 seconds (0902–55).

3. **Distance to New Course.** If this method is used for the turn shown in figure 19, the ship is plotted on her new course from the point C, where the new course laid back cuts the original course produced, the ship putting her rudder over at A, as before, and passing through the point B.

It has already been explained how the loss of speed during the turn is allowed for by a time correction which gives the corrected time at which the ship starts on her new course from B. Clearly, then, if the time taken by the ship to steam from C to B at her original speed is subtracted from this corrected time for B, the corrected time at which the ship starts on her new course from C is obtained.

The following is an example of a 'distance to new course' table constructed for a battleship, speed 15 knots, using 10° of rudder :

Alteration of Course.	Distance to New Course.		Time Correction.	
Degrees.	*Yards.*	*Miles.*	*m.*	*s.*
20	250	0·12	+0	43
40	384	0·19	+1	04
60	493	0·24	+1	24
80	608	0·30	+1	36
100	753	0·38	+1	50
120	975	0·49	+1	52
140	1,400	0·70	+1	35

If the table in the example shown in figure 19 is used, the point C is plotted 864 yards along the original course 000°, and the time correction is 1 minute 51 seconds (0901–51).

This method has :

(a) the advantage of doing away with any intermediate course and requiring only two small corrections :

(i) a distance to be added to the original course.

(ii) a time correction to be added to the time of 'wheel over' to obtain the corrected time for the point C.

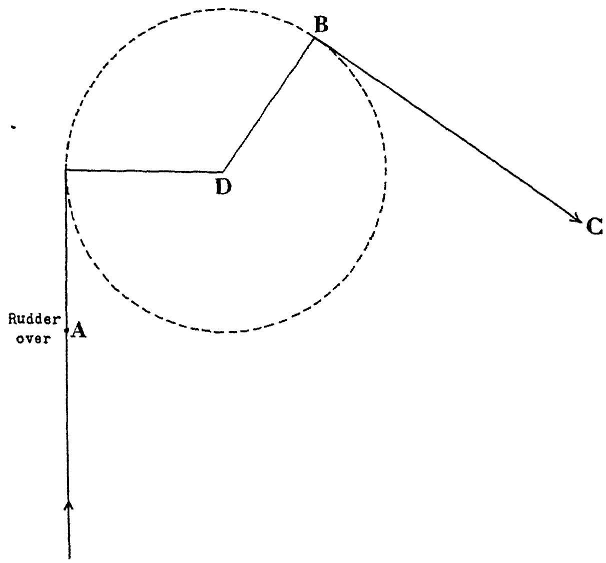


FIGURE 20.

(b) the disadvantage that it cannot be used for alterations of course over 150°, because above this point the distance to new course becomes excessive.

4. **Drawing the Turning Circle with Compasses.** This method, shown in figure 20, is not as accurate as the 'advance and transfer' method.

Set the compass spring bow to half the tactical diameter, and choosing by eye the point D a little in advance of the point A where the rudder was put over, describe a circle with centre D. Draw the new course BC as a tangent to this circle, and write the actual time the ship steadied on this course against the point B.

5. **Plotting the Mid-Time of the Turn.** Note the mid-time of the turn and plot the ship along the original course until this time. From the point obtained continue to plot on the new course.

This method, shown in figure 21, gives a close approximation, and the loss of speed is partly allowed for, but it should not be used when great accuracy is required.

6. **Plotting the Advance and Transfer.** This method of plotting is shown in figure 17.

7. **Using a Protractor Cut to Represent the Turning Circle.** This method has the disadvantage of requiring a large number of protractors. A different protractor will be required after each speed alteration and each change of scale on the plotting sheet or chart.

Correction for Change of Speed. When speed is changed on a straight course, allowance must be made for the fact that the ship takes time to gather or lose way, even if the engines perform the new revolutions at once.

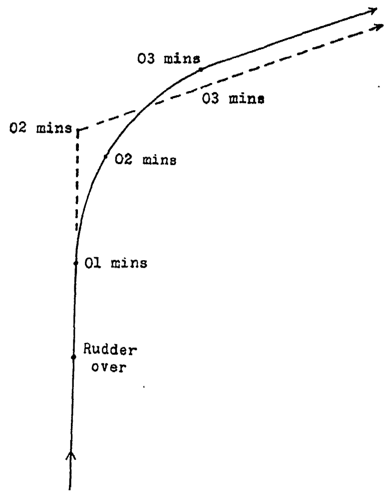


FIGURE 21.

For heavy ships a correction of about 100 yards per knot of increase or decrease must be applied to the distance run, + when speed is reduced and — when speed is increased.

NOTE. The actual correction for any ship is found during turning trials and is noted in the *Navigational Data Book*.

Allowance for wind must also be made for large turns, because a ship turns quicker into the wind than away from it.

Recording the Data. The following example illustrates the method that is recommended.

From 0900 to 1000 ship steamed 000°, 15 knots.
at 1000 altered course to 030°, ,,
,, 1015 ,, ,, ,, 135°, ,,
,, 1022 ,, ,, ,, 142°, ,,
,, 1027 altered course 180° to port,
,, 1040 decreased to 12 knots.
,, 1100 required position.

1. Time Correction.		2. From (corrected time).			3. To rudder over.			4. Course.	5. Speed.	6. Distance.	7. Remarks.
m.	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*Kn.*	*Miles.*	
		09	00	00	10	00	00	000°	15	15·00+·15	
0	54	10	00	54	10	15	00	030°	15	3·52+·40	
1	50	10	16	50	10	22	00	135°	15	1·29+·04	
0	14	10	22	14	10	27	00	{142°	15	1·19	
								{075°	15	0·43	
4	53	10	31	53	10	40	00	322°	15	2·03	
		10	40	00	11	00	00	322°	12	4·00+·15	

The above forms can be made out on a board and will suit either method.

In the last example, the 'distance to new course' method is used for small alterations of course, and the 'intermediate course' and distance method for the 180° turn.

At 1000 the rudder is put over and the time entered in column 3, and the new course 030° in column 4 below the last course.

In column 1 insert abreast the new course the time correction

SLIDE RULE USED AS A SPEED AND DISTANCE SCALE
SET FOR A SHIP'S SPEED OF 12 KNOTS

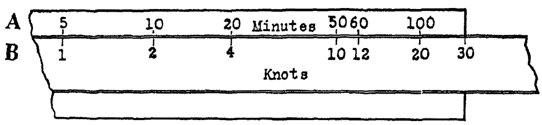


FIGURE 22.

from the 'distance to new course' table for 30° (0 m. 54 s.). Add this to the time of putting the rudder over and insert the result in column 2. The 'distance to new course' for 30° is entered in column 6 as an addition to the distance run.

At 1027 course is altered 180° to port, and an intermediate course (075°) is required. Enter this course between the old and new courses in column 4, and the distance 0'·43 in column 6. Bracket the two courses.

The time correction (4 m. 53 s.) must be entered in column 1 abreast the new course 322°.

At 1040, when speed is reduced to 12 knots, 3×100 yards, or 0'·15, must be added to the distance run in column 6.

Plotting Chart. If the scale of the chart is not suitable for plotting, use a diagram 5004 or 5004 (a). These diagrams are supplied with all charts sets.

The Distance Scale. There are several methods of calculating the distance run at varying speeds during a period.

1. The best method is to use a *slide rule* as shown in figure 22.

Let scale A represent time in minutes and scale B the ship's speed in knots.

Keep the ship's speed on scale B set against 60 on scale A.

The distance run during any time interval can then be read direct from scale B. In figure 22 the slide rule is set for a ship's speed of 12 knots.

To Find the Ship's Speed when the Distance Run is Known. Set the distance run on scale B against the time interval on scale A. The ship's speed can then be read off on scale B, directly below the 60 on scale A.

2. A table showing the distance run in a given interval at speeds between 7 to 30 knots is included in the large envelope supplied with chart sets.

3. When diagrams 5004 or 5004(*a*) are used, the latitude and longitude scale at the bottom right-hand corner can be converted into a time-distance graph by using the lower horizontal margin as a scale of time and the left-hand vertical margin as a scale of distance.

CHAPTER IV

FIXING BY OBSERVATION OF TERRESTRIAL OBJECTS: TIDAL STREAM PROBLEMS

In Chapter III the estimated position was defined as the position found from the courses steered and the estimated speed through the water, together with any allowance for the distance the ship has been moved by the tidal stream, current, wind and sea.

This position is liable to error, and it is therefore always necessary for the navigator to find the ship's position by taking observations of objects which are shown on the chart, or in default of these, by observing heavenly bodies.

POSITION LINES AND FIXES

A position line on a chart is any line, straight or curved, on some part of which the ship's position lies.

A fix is the position obtained by the intersection at a suitable angle (see page 47) of two or more position lines obtained at practically the same time.

A running fix is the position found by using two position lines obtained at different times, and allowing for the ship's run and the effects of the tidal stream, current and wind, during the interval.

METHODS OF OBTAINING A POSITION LINE

A position line can be obtained by:

1. *a compass bearing.*
2. *a relative bearing.*
3. *a transit.*
4. *a horizontal sextant angle.*
5. *a vertical sextant angle of an object of known height.*
6. *a range by distance meter when the height of the object is known.*
7. *a range by rangefinder.*
8. *a horizon range.*
9. *sounding.*
10. *an echo of the siren.*
11. *W/T-D/F bearings* as explained in Chapter V.
12. *radio sound ranging* }
13. *submarine sound ranging* } as described in Volume III of this Manual.
14. *taut-wire measuring gear* }
15. *an astronomical observation* as outlined in Appendix III of this Volume, and described in detail in Volume II of this Manual.

When position lines are drawn on the chart, it is usual to mark them with single arrow heads to distinguish them from other lines on the chart. When a position line is *transferred*, it should be marked with double arrow heads.

1. **A Compass Bearing.** Suppose a lighthouse is observed from a ship to bear 100° by compass. Then if a line is drawn in the reverse direction (280°) from the position of the lighthouse on the chart, it is clear from figure 23 that any observer from whom the lighthouse bears 100° must be situated somewhere on this line.

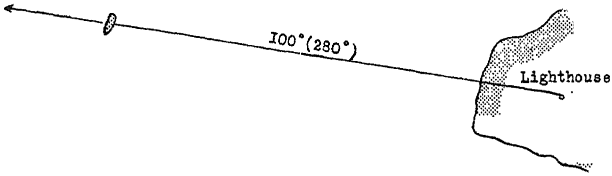


FIGURE 23.

This position line is known as a *line of bearing.*

NOTE. When a bearing of the edge of the land, etc., is taken it is usual to distinguish the right-hand edge with the symbol →| and the left-hand edge with the symbol |←.

2. **A Relative Bearing.** A line of bearing can also be obtained by noting the direction of an object relative to the direction of the ship's head, that is, by an angle on the bow.

If the lighthouse shown in figure 24 is observed to be 60° on the

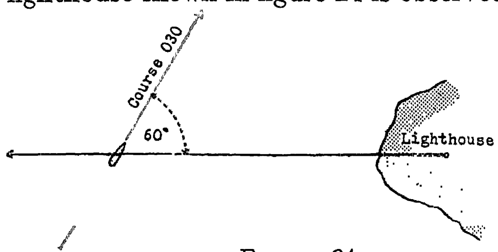


FIGURE 24.

starboard bow (or Green 60°) when the ship is steering 030°, it is clear that the bearing of the lighthouse is 090°, and a line of bearing can be drawn on the chart.

3. **A Transit.** If an observer sees two objects in line, then he must be situated somewhere on the line (produced) which joins them, as shown in figure 25. This gives an excellent position line when the distance between the observer and the nearer object does not exceed three times the distance between the objects in transit.

A transit is usually shown by the symbol ϕ.

NOTE. If the bearing of the objects is taken when they are in transit, the error of the compass can be found.

4. **A Horizontal Sextant Angle.** Since all angles in the same segment of a circle are equal, it follows that, if the observer measures the horizontal sextant angle between two objects, he must lie somewhere on the arc of a circle that passes through them, and contains the angle observed.

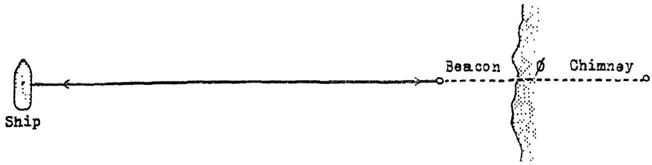


FIGURE 25.

In figure 26, the angle between the lighthouse and the chimney has been measured by sextant and found to be 80°.

5. **A Vertical Sextant Angle of an Object of known Height.** If the angle subtended at the observer's eye by a vertical object of known height is measured, the solution of a right-angled triangle will give the observer's distance from the base of the object. The position line will then be the circumference of a circle.

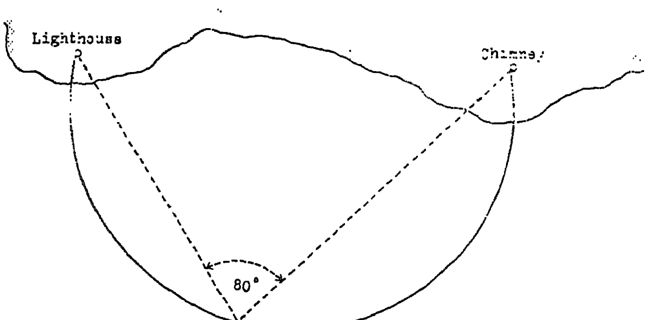


FIGURE 26.

Lecky's Vertical Danger Angle and Off-Shore Distance Tables solve this triangle by using the height of the object and the corrected observed angle. The tables are divided into two parts.

Part I. For use when the object is between the observer and the horizon. Heights up to 1,100 *feet. Distances up to* 5 *miles.*

It assumes that:

(*a*) the observed angle is part of a right-angled triangle.
(*b*) there is no refraction or curvature of the Earth.
(*c*) the height of the observer's eye is zero.
(*d*) the foreshore is vertically below the object.

Usually the error caused by these assumptions is negligible when the distance between the ship and the shore is greater than the distance from the shore to the point below the object.

The distance found is the distance of the object and not that of the foreshore.

The observed angle must be corrected for index error and the height of the object amended for the height of tide.

Example. A vertical sextant angle of the top of the lighthouse, height 125 feet, shown in figure 27, is observed as 0° 25′ 15″

Index error	15″+
Corrected angle	0° 25′ 30″

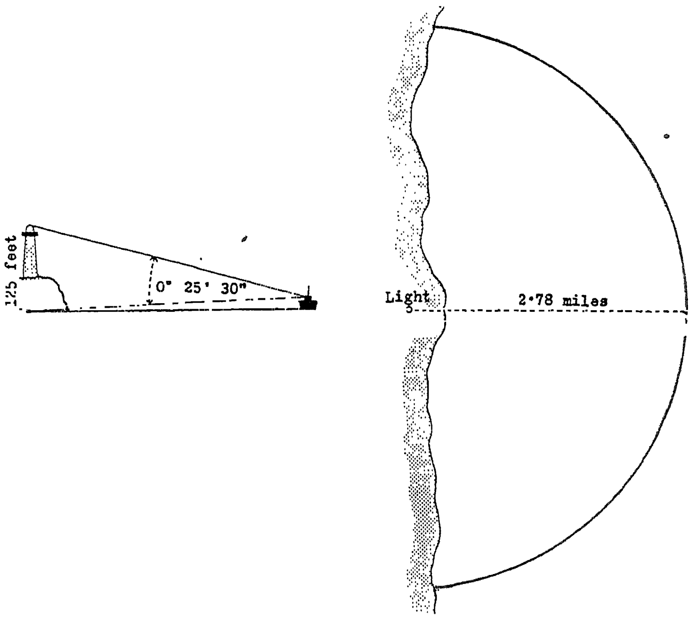


FIGURE 27.

Part I of *Lecky's Tables,* entered with a height of 125 feet and an angle of 0° 25′ 30″, gives the distance as 2·78 miles.

The position line, therefore, is the circumference of a circle of radius 2·78 miles, drawn with the lighthouse as centre.

Part II. For use when the object is beyond the horizon. Heights up to 18,000 *feet and distances of* 5 *to* 110 *miles.*

The following corrections must be applied to the observed angle :

(*a*) the index error.

(*b*) a correction for refraction obtained by dividing the estimated distance in miles by twelve. The result of this division gives the refraction correction *in minutes* which must be *subtracted* from the observed angle.

(*c*) a correction for dip, given on page 46 of the tables, which must always be subtracted from the observed angle.

NOTE. If the estimated distance is found to be much in error, a second approximation will be necessary.

Example. A vertical sextant angle of a mountain of 5,400 feet, distant approximately 24 miles, as shown in figure 28, is observed from a height of eye of 25 feet and found to be 1° 57′ 20″

Index error of the sextant ..	40″+
	1° 58′ 00″
Dip correction	5′ 19″−
	1° 52′ 41″
Refraction correction $\frac{24}{12}=2'$	2′ 00″−
True angle	1° 50′ 41″

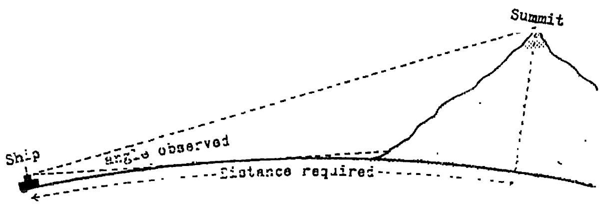


FIGURE 28.

Part II of *Lecky's Tables,* entered with a height of 5,400 feet and an angle of 1° 50′ 41″, gives the distance as 24·8 miles.

6. **By a Range taken with a Distance Meter when the Height of the Object is Known.** This method is based on the principle of the vertical sextant angle.

There are two types of distance meters supplied to H.M. ships. They are fully described in Chapter VIII.

(*a*) *The Stuart's Distance Meter,* used for short distances up to one mile.

(*b*) *The Weymouth Cooke Sextant Rangefinder,* used for distances from 1 to 9 miles.

These instruments are useful because they give the distance quickly.

The position line is the circumference of a circle, the radius of which is the distance found by the instrument.

7. **By a Rangefinder.** This method is useful for finding the distance of a single light at night or an object unsuitable for a vertical sextant angle.

8. **By an Horizon Range.** This method is most useful at night

for finding the distance of a light when it appears in view above the horizon or dips below the horizon.

The distance of the ship and the light from the horizon can be found either from *Stevenson's Table* in the *Admiralty Light Lists*, or from Table A in *Lecky's Tables*. These distances added together give the distance of the ship from the light.

NOTE. When the distance at which a light will come into view is calculated, it is necessary to consider the power of the light. This information is given in the *Light Lists* described on page 33.

Example. A shore light 150 feet above the water is observed from the bridge to dip below the horizon. If the height of eye on the bridge is 40 feet, what is the distance of the light?

Stevenson's Table gives:

the distance of the horizon from the light (150 feet) .. .. =14·02 miles
the distance of the horizon from a height of eye of 40 feet .. .. = 7·26 miles

The distance from the light to the bridge is therefore 21·28 miles

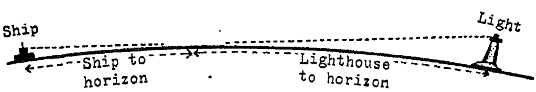


FIGURE 29.

The distance found by *Stevenson's Table* and *Lecky's Table* A will differ slightly because they are based on different allowances for refraction. If the above example is worked by *Lecky's Table* A, the distance is seen to be 21·35 miles.

9. **By a Sounding.** An approximate position line can be obtained from soundings. For example, on making the English Channel from the Bay of Biscay, it is seen that the 100 fathom line is clearly marked on the chart. Thus, when a sounding of 100 fathoms is obtained, the ship must lie somewhere on this line.

Similarly a particular fathom line, if it is clearly defined, may be picked up and will give a position line which may be used to clear some danger. A good example of this is given on page 144.

The nature of the bottom, which is found by sounding, can occasionally be used to give an approximate position line when the different formations are clearly defined on the chart. For example, in the channel leading up the River Plate, the 'Mud Wall' indicates the fairway. On one side the bottom is formed of sand and on the other side are stones.

10. **By Echo of the Siren.** If the echo of the siren from cliffs can be heard it is possible to calculate the distance of the cliff and so

obtain a position line. Take the accurate time interval between the making of the sound and the returning echo, then :

$$\left.\begin{array}{l}\text{the distance in feet of}\\ \text{the ship from the cliff}\end{array}\right\} = \frac{\text{the time interval in seconds} \times 1130}{2}$$

An approximation of the distance is :

distance in cables=time interval in seconds$\times$9/10ths.

TRANSFERRING POSITION LINES

It frequently happens that only one position line is obtainable at a given moment. This single observation, however, can be made use of later when a second observation is possible.

Suppose, in figure 30, that a lighthouse bore 280° from the ship at 0900. The ship is steaming 200° at 10 knots. What information about the ship's position at 0930 is there?

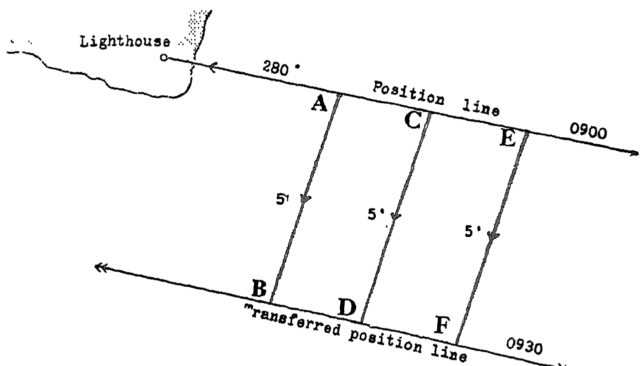


FIGURE 30.

Draw a line ACE in a 100° direction from the light. This is the position line at 0900.

Suppose three lines are drawn, AB, CD, EF, each in a direction 200° and each 5 miles in length (the ship's run in half an hour). Then if the ship is at A at 0900, and is subsequently unaffected by wind, stream, etc., she will be at B at 0930. Similarly if the ship is at C or E at 0900, she will be at D or F at 0930.

Then since ACE is the position line at 0900, BDF must be the position line at 0930; that is, the original position line has been transferred, and the new line is known as the *transferred position line*. The transferred position line is parallel to the original position line and is usually distinguished by two arrow heads on each end.

If the ship is set by the tidal stream, current or wind during the run, the point through which to draw the position line must be arrived at by two steps, as shown in figure 31.

(*a*) Lay off from any point on the original position line the course and distance *steamed* by the ship in the interval (AB).

(*b*) From the end of this line, at B, lay off BK, which is the direction and distance the ship is estimated to have been set in the

interval by tidal stream, current or wind. The position line is now transferred through K.

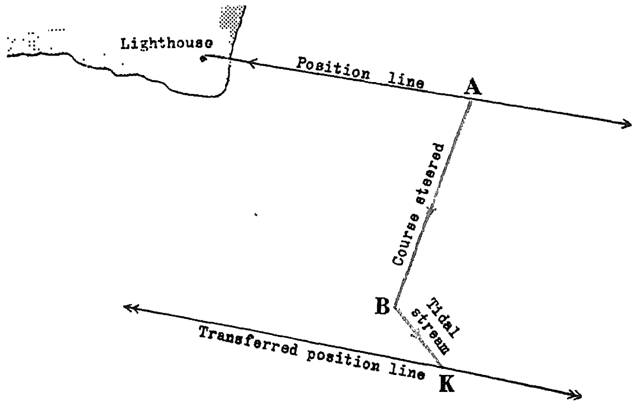


FIGURE 31.

THE USE OF A SINGLE POSITION LINE

When two position lines cannot be obtained, a single one may often be of use in clearing some danger or making a harbour. In figure 32, suppose the course to be steered up a narrow harbour is 080°.

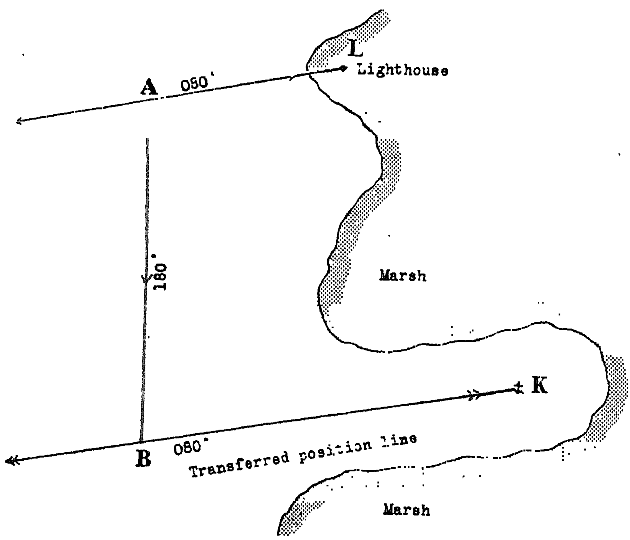


FIGURE 32.

Then the ship, steaming 180°, observes the time at which the lighthouse L bears 080°. The time taken to run the distance AB is calculated, and at the end of this time the ship alters course to 080°. It is clear that no matter where the ship was on the original

position line AL, she will turn onto the transferred position line, BK, which will lead her into harbour.

FIXING THE SHIP

A fix has been described as the position obtained by the intersection, at a suitable angle, of two or more position lines, obtained at practically the same time.

The following combinations of position lines give a fix:

1. *cross bearings.*
2. *a bearing and an angle.*
3. *a bearing and a distance.*
4. *a bearing and a sounding.*
5. *a bearing and a horizontal angle.*
6. *a transit and an angle.*
7. *horizontal sextant angles.*
8. *two bearings, one of which is transferred. (A running fix.)*
9. *a line of soundings.*

Before these methods are dealt with in detail, the following points should be noted and borne in mind.

Before Fixing. The navigator should identify all the objects he is going to use and also make sure that they are marked on the chart. It is no use taking the bearing of one conspicuous object and then having to look about to select the others.

When Taking Cross Bearings. The names of the objects should be written down in the notebook. After this the bearings should be observed as quickly as possible, and care taken that the object the bearing of which is changing most rapidly is the last object to be observed, except prior to anchoring, when the most rapidly changing bearing should be observed first. The bearings should be written against the names of the objects in the notebook, and also the time of the fix. The time noted should be that at which the last bearing was observed.

The time, to the nearest minute, should be written against all fixes on the chart.

Unless the bearings are taken almost simultaneously, it is impossible to obtain a satisfactory cut, especially if the first bearing is changing rapidly. *The most favourable circumstances are when the first object is observed nearly ahead and the second nearly abeam.*

Remember when using a magnetic compass, that the deviation which must be used to correct the bearings, is the deviation for the direction of the ship's head when the observations were taken.

Choosing Objects. When a ship's position is fixed by three bearings, the objects chosen should, if possible, be so placed that their bearings differ by about 60°. The position lines will then make a good cut.

If it is possible to fix by two bearings only, the objects selected should be such that their bearings differ as near as possible by 90°.

The effect of any small errors in taking the observations and laying them off on the chart, is least when the angle of cut is 90°, and gradually increases as the angle of cut decreases.

In no circumstances should a cut of less than 30° *be accepted for a fix.*

Figure 33 shows the difference in position caused by an error of 5° with a 90° cut and with a 15° cut, A being the correct and B the incorrect position.

Always choose objects near the ship in preference to objects far away because:

(*a*) any error in the bearing of a nearby object has less effect on the accuracy of the final position than a similar error in the bearing of an object far away.

(*b*) on account of distortion, long lines of bearing drawn on a chart are not so accurate as short lines.

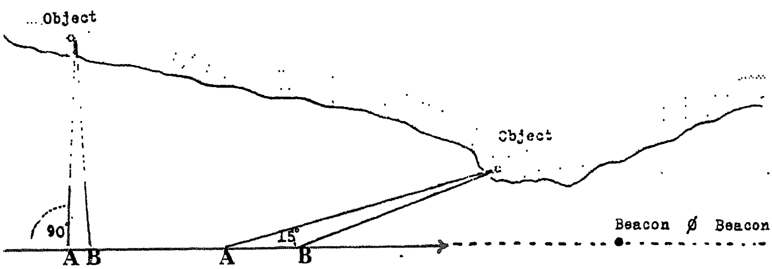


FIGURE 33.

If the ship is on the circumference of a circle passing through the three objects, the three lines of bearing will always meet at a point, even when there is a large unknown compass error. This is clearly shown in figure 35.

If the ship is in a channel where it is possible that the two sides were surveyed separately, all the objects used in fixing her should be on the same side of the channel.

1. **Fixing by Cross Bearings.** When lines of bearing are obtained from two different objects at the same time, the ship must be on both lines simultaneously. That is, if the lines of bearing cut at a suitable angle, her position lies at the point of intersection.

Suppose, in figure 34, that the lighthouse bore 040° and the church bore 125° to an observer on board a ship at 1015. If these two lines are drawn on the chart, the point of their intersection must be the ship's position at 1015.

To avoid error, a third bearing, called a check bearing, should

be taken. This bearing should pass through, or close to, the point of intersection of the other two bearings. In figure 34 a check bearing of the beacon was 075°.

The Cocked Hat. It is often found in practice that the three bearings, when plotted, form a small triangle known as a *cocked hat.* If the cocked hat is reasonably small, the position of the ship is usually taken to be inside it. The theory of the cocked hat, derived from both terrestrial and astronomical position lines, is dealt with at length in Volume III.

If the cocked hat is large, the work should be revised to ensure

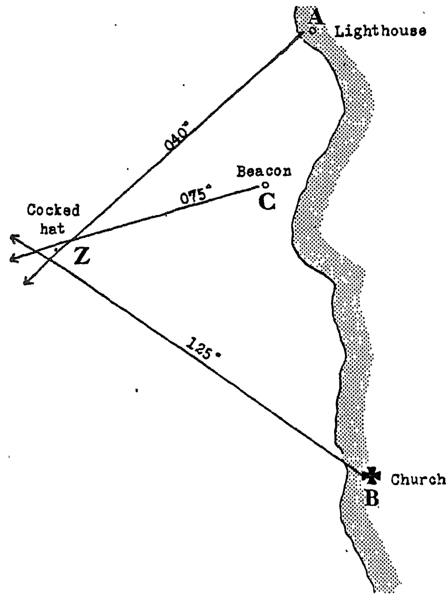


FIGURE 34.

that the objects have been properly identified and that there was no error in correcting the bearings.

If the cocked hat remains, the position of the ship should be taken at the corner of the triangle which will place her nearest to danger. This will ensure that subsequent alterations of course for rounding marks etc., will have a probable safety margin.

As the cocked hat may be caused by unknown deviation or gyro error, every endeavour should be made to check the deviation or error of the compass by the methods explained in Chapters IX and X.

Example of a Bad Fix by Cross Bearings.

It is seen in figure 35 that:

(*a*) the ship and the three chosen objects lie on the arc of a circle, and that the three bearings will cut at a point whatever the unknown error is.

(*b*) the conspicuous chimney should not have been chosen when there was a beacon on a nearly similar bearing *much closer* to the ship.

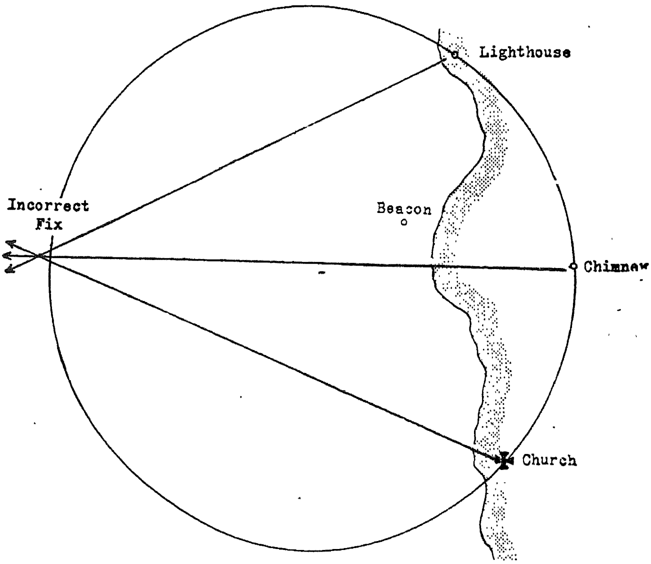


FIGURE 35.

2. **Fixing by a Bearing and Angle.** It may happen that only one object is visible from the compass, but another object can be seen from the wing of the bridge. The sextant angle subtended by the two objects must then be observed.

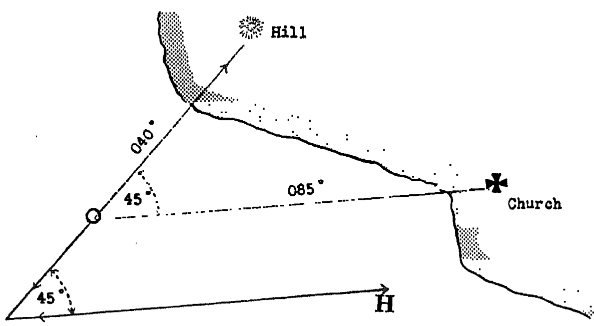


FIGURE 36.

To lay off a bearing and angle, either of the following methods can be used :

(*a*) Apply the angle to the observed bearing and thus obtain the bearing of the other object not visible from the compass. In figure 36, a hill bears 040° and the sextant angle to a

church is 45°; hence the church bears 085°, and the fix can now be laid off as cross bearings.

(b) Through the hill draw the line of bearing 040°; from any point A on this line lay off an angle of 45° on the side towards the church; lay the parallel rulers along the line, AH, so obtained and run them down until the edge is on the church. The point where the edge of the rulers cuts the line of bearing from the hill is the ship's position.

NOTE. (i) It is advisable, if possible, to take a second angle as a check.
(ii) If possible, select an object that is nearly at right angles to the line of bearing.

3. **Fixing by a Bearing and Distance.** This is an exceedingly useful method of fixing the position quickly when only one object is in sight. The distance of the ship from the object can be found by:

(a) a rangefinder or distance meter, as explained on page 66.
(b) a vertical sextant angle, as explained on page 64.
(c) a horizon range, as explained on page 67.

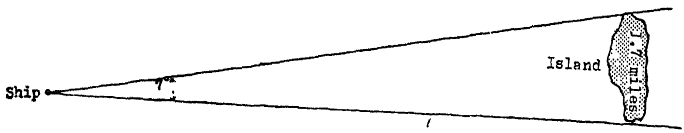


FIGURE 37.

4. **Fixing by a Bearing and Sounding.** On approaching the land in places where the depth changes fairly rapidly, an approximate position can be found by observing a bearing and sounding at the same time.

Remember:

(a) When using sounding tubes, make allowance for the height of the tide and the height of barometer before comparing the soundings with the chart.

(b) The fix will not be reliable unless the fathom lines are very clearly defined.

(c) Cross the fathom lines, as nearly as possible, at right angles.

5. **Fixing by a Bearing and Horizontal Angle.** This method is most useful when the ship is passing a small island. The compass bearings of the two extreme edges of the island would give too small an angle of cut. Therefore measure the angle between the edges by sextant and observe the bearing of one edge; then measure the width of the island on the chart and calculate its distance from the ship.

Example. The sextant angle between the extremes of an island 1·7 miles wide, shown in figure 37, was found to be 7°, and at the same time the left-hand edge bore 085°.

To find the distance of the ship from the island, let R miles equal the distance. Then, since arc=radius×the angle in radians :

$$\frac{R}{1\cdot7}=\frac{360}{2\pi\times7}$$

$$\therefore R=14 \text{ miles (approximately).}$$

6. **Fixing by a Transit and an Angle.** This method is similar to that of fixing by a bearing and an angle, but since no compass is used, it has the advantage of eliminating any compass errors.

It is frequently used for fixing boats' positions when soundings are carried out during a survey.

7. **Fixing by Horizontal Sextant Angles.** This method fixes the ship by the intersection of two or more position lines, found by observing the horizontal sextant angles subtended by three or more objects.

The method is extremely useful :

(*a*) for fixing the ship when moored or at anchor.
(*b*) at sea, when two trained observers are available.

Its advantages are :

(i) it is more accurate than a compass fix, because a sextant can be read more accurately than a compass.
(ii) it is independent of compass errors.
(iii) the angles can be taken from any part of the ship.

Its disadvantages are :

(i) it takes longer than fixing by compass bearings.
(ii) three suitable objects are essential.
(iii) if the objects are incorrectly charted, the fix will be false and the error may not be apparent. For this reason, *when a poorly surveyed chart is used, the ship's position should be fixed by compass bearings* because inaccuracies in the charted position of objects will become apparent when simultaneous lines of bearing drawn on the chart do not meet at a point.

If A and B, shown in figure 38, are two objects on shore approximately in the same horizontal plane as the observer, and the angle between them is observed, the ship must lie on the segment AOB which contains the observed angle.

Similarly if the angle between B and C is observed, the ship lies on the segment COB.

These segments intersect at B and O, and O must be the ship's position.

To Plot the Fix it is not necessary to draw the circles. The three lines, OA, OB and OC may be drawn on tracing paper so that the angles at O are those observed. The paper is placed over the chart so that OA, OB and OC pass through A, B and C respectively, and the position O can be pricked through.

More convenient methods of plotting this type of fix are by:

(*a*) Douglas' protractor as described on page 203.

(*b*) station pointer as described on page 201.

A Check Angle should be taken, if possible, from the centre object to a fourth object. To plot this angle after the fix has been obtained when a station pointer is used, hold the instrument steady

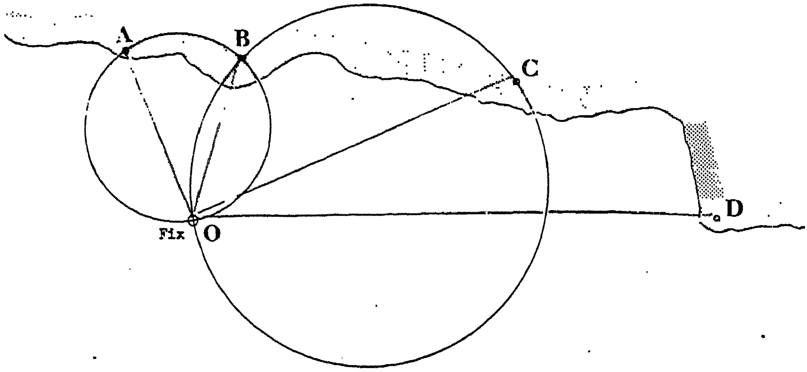


FIGURE 38.

and move one of the legs to the check angle. The leg should pass through the fourth object.

The fix from the above figure would be written down in the note-book: A 39° B 50° C
73° D

Choosing Objects. It is clear from figure 35 that if the light-house, chimney and church are on the arc of a circle passing through

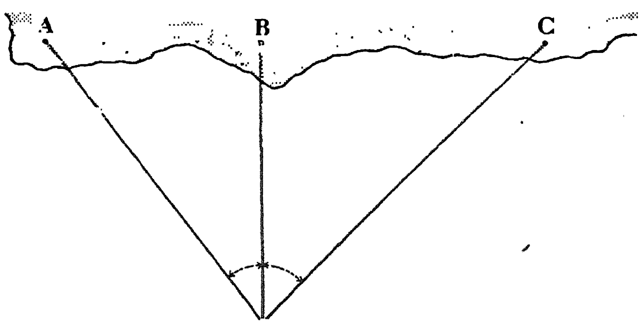


FIGURE 39.

the ship, then she may be anywhere on the circumference of the circle and no fix is obtained.

To avoid this occurrence, the objects must be carefully chosen so that:

(*a*) they are either all on, or near, a straight line as shown in figure 39.

(b) the centre object is on the ship side of the line joining the other two, as shown in figure 40.

(c) the ship is inside the triangle formed by the objects as shown in figure 41.

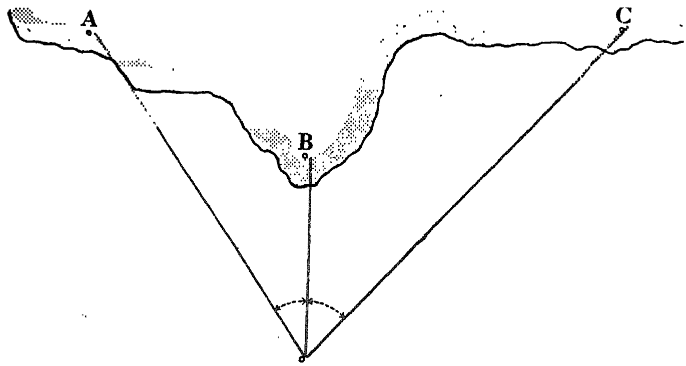


FIGURE 40.

8. **A Running Fix.** If two position lines are obtained at different times, the position of the ship can be found by transferring the first position line up to the time of taking the bearing for the second position line as described on page 68. The point of intersection

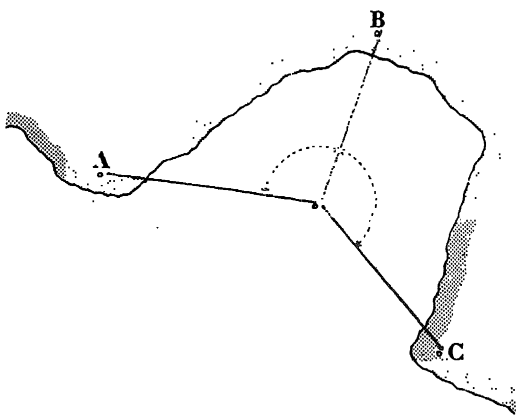


FIGURE 41.

of the second position line and the transferred position line is the ship's position at the time of the second observation.

The accuracy of this fix will depend on the accuracy of the estimated run between bearings and, therefore, *it is essential to take great care that allowance is made for the tidal stream, current and wind experienced by the ship during this interval.*

Example. A ship is steering 090° at 8 knots. The tidal stream is estimated as setting 135° at 3 knots.

At 1600 a lighthouse bore 034°.

At 1630 the same lighthouse bore 318°.

In figure 42, A is any point on the first position line.

AB is the course and distance run by the ship in 30 minutes.

BC is the amount of tidal stream experienced in 30 minutes.

The point where the first position line, transferred and drawn through C, cuts the second position line is the ship's position at 1630.

Doubling the Angle on the Bow is a special form of running fix which can be plotted either in the way already described or by a quicker method resulting from the relation between the angles.

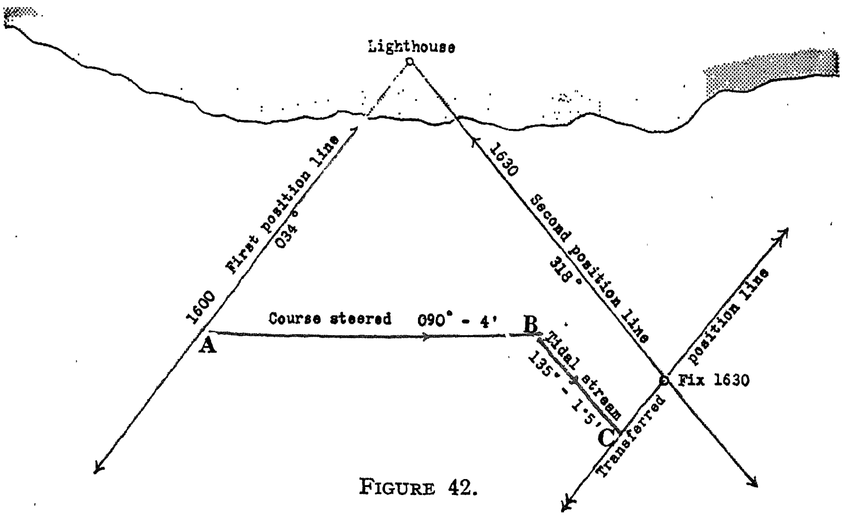


FIGURE 42.

Suppose the angle between the ship's head and the bearing of the light shown in figure 43, is measured as $\alpha°$ and the time noted. If the time is noted when the angle is $2\alpha°$, it follows that the distance of the ship from the object at the second observation is equal to the distance run by the ship during the time between the two observations.

If the bearings are taken when the angles are 45° and 90° from the ship's course (on the bow and the beam) the fix obtained is known as *a four point bearing.*

Doubling the angle on the bow *cannot be used,* in its simple form, if there is any tidal stream, current or leeway *across the course,* that is, if the course made good is not the course steered. If this happens, the observations must be plotted as a running fix.

A similar method which gives the distance a ship will pass abeam of an object is illustrated by the following example.

Take the time when the angle on the bow is 35° and again when it is 67°; *the distance run over the ground in the interval will be approximately the distance the ship will pass abeam of the object.*

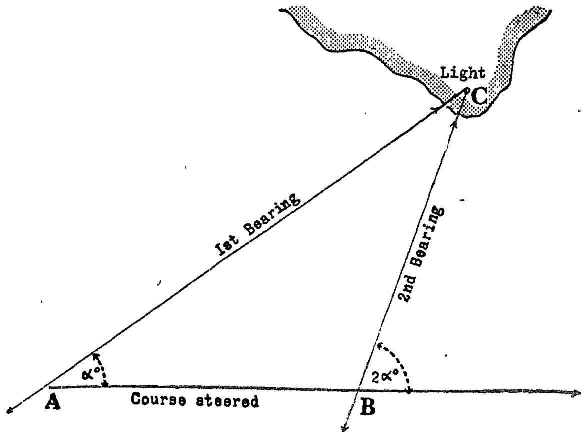


FIGURE 43.

In figure 44, AB=LC, but only if the course made good is the same as the course steered.

NOTE. 37° and 72° give the same result.

9. **By a Line of Soundings.** When there are no objects suitable for fixing it is sometimes possible to obtain a fix by sounding.

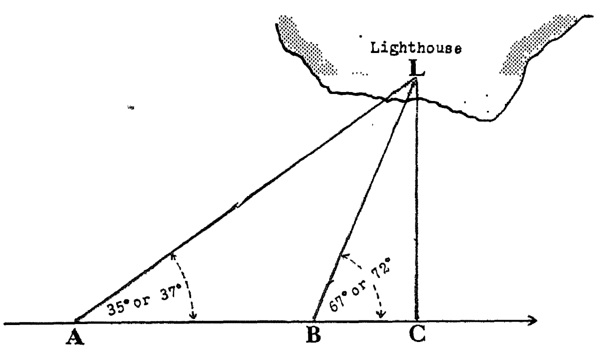


FIGURE 44.

Sound at regular intervals, noting the depth and nature of the bottom in the sounding book. If chemical tubes are used, the soundings must be corrected for the height of the barometer and the height of the tide as described in Chapter VIII.

On a piece of tracing paper draw a few lines representing meridians. Lay off the ship's course made good and allow for any

tidal stream, current or wind. Along this course plot the reduced soundings on the scale of the chart in use. Place the tracing paper on the chart in the vicinity of the ship's estimated position, and using the meridians as a guide in keeping it straight, move it about and see if the soundings on the tracing paper will coincide with those on the chart.

The frequency at which soundings should be taken depends on the speed of the ship and the spacing and nature of the soundings on the chart.

Caution. *The approximate position found from a line of soundings should always be used with caution because it is often possible to fit in a line of soundings in several positions on a chart.*

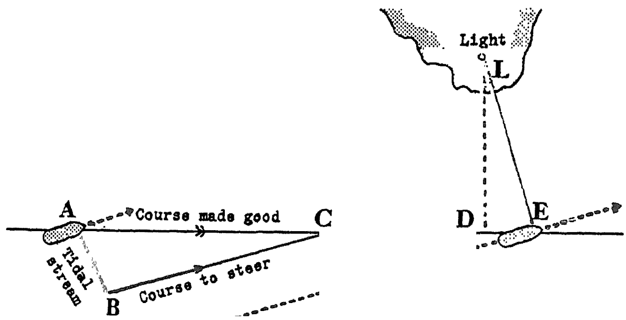


FIGURE 45.

TIDAL STREAM AND CURRENT PROBLEMS

In Chapter III the method of working up the estimated position by making allowance for the tidal stream and the effect of the wind was described. Furthermore, in the description of a running fix in this chapter, the tidal stream was allowed for in a similar way.

There are, however, other problems concerning the allowances to be made for tidal stream.

1. *To find the time when an object will be abeam, allowing for a tidal stream.*

Example. A ship at A shown in figure 45, steers so as to make good a course 090° allowing for a tidal stream setting 140°. When will the lighthouse L be abeam ?

Find the course to steer, BC, by the method explained on page 52. The light is abeam when it bears 90° from the course steered, that is when the ship is at E, and *not* when the ship is in position D. The time elapsed will be the time taken to go the distance AE at a speed represented by AC. This is the speed made good.

2. *To find the direction and the rate of the tidal stream experienced between two fixes.*

Example. A ship is at A at 0100 as shown in figure 46, and then steers 110° at 10 knots. At 0300 she fixes herself at B. What is the direction and rate of the tidal stream from 0100 to 0300 ?

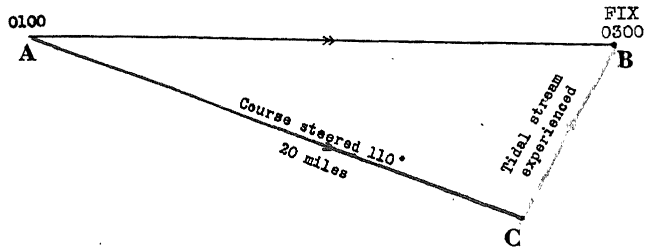


FIGURE 46.

Plot the ship's track 110°, 20′ from A. Then the difference between this dead reckoning position and the observed position at 0300 gives the direction of the tidal stream CB (045°) and the distance it has taken the ship in 2 hours. From these data the rate can be calculated.

The tidal stream was setting 045° at 3·7 knots.

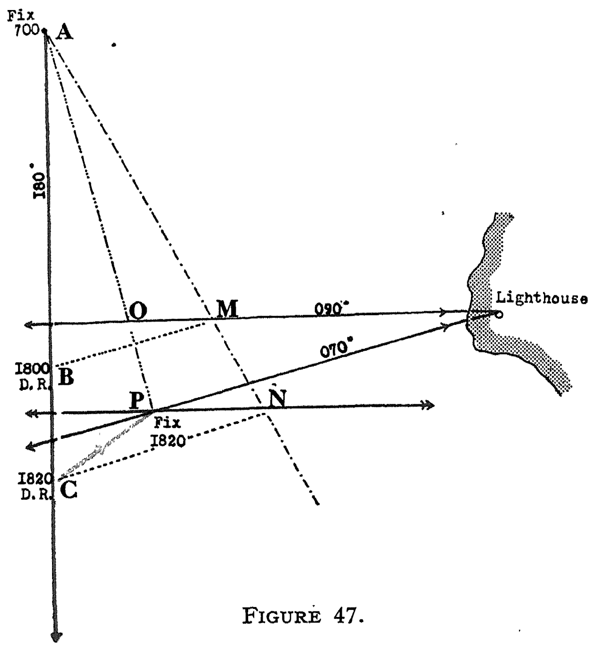


FIGURE 47.

3. *To obtain a fix from two bearings with a run between, given a previous fix but an unknown tidal stream.*

Example. At 1700 a ship was at A steering 180°. At 1800 the

bearing of a lighthouse was 090°. At 1820 the bearing was 070°. Required the fix at 1820 and the tidal stream experienced from 1700 to 1820.

Plot the D.R. positions at 1800 and 1820 (B and C in figure 47). Draw any line BM to cut the first bearing in M. Join AM and produce it. Draw CN parallel to BM to cut AM produced in N. Then

$$\frac{MN}{AM} = \frac{BC}{AB}$$

Draw NP parallel to the first bearing to cut the second bearing in P. Then P is the ship's position and CP the tidal stream experienced, since:

$$\frac{OP}{AO} = \frac{MN}{AM} = \frac{BC}{AB}$$

Therefore the line AP is divided in the correct proportion for time, and O and P fall on the position lines given by the bearings.

NOTE. This method should be used only when there is a short run because it is inaccurate if the tidal stream is not constant.

CHAPTER V

FIXING BY W/T—D/F

When a ship or shore station transmits a wireless signal, energy is sent out in all directions. A simple analogy is the light sent out from an unscreened lamp at the masthead. A suitable aerial system and W/T receiver can be used to indicate the direction of the W/T transmitter, just as the eye can detect the direction of the light. Each bearing provides a position line.

The wireless energy from the transmitter can be considered as consisting of two components, called the *ground ray* and the *atmospheric ray*, as shown in figure 48.

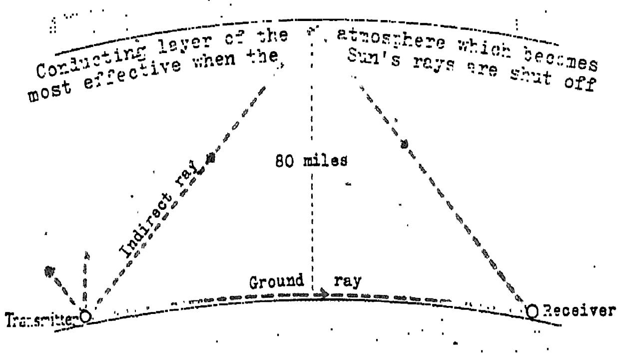


FIGURE 48.

The Ground Ray is propagated horizontally over the Earth's surface and follows the path of shortest time between any two places, that is, the great-circle track.

The Atmospheric Ray is propagated upwards in all directions into the upper atmosphere, and part is reflected back to the Earth's surface. The distance from the transmitter at which the effect of this reflected atmospheric ray becomes appreciable varies with the time of day, but in general the distance is considerably shorter by night than by day.

A D/F receiving system affected only by the ground ray will give reliable bearings correct within 1°, but if it is also affected by the reflected atmospheric ray, errors will be produced. This type of error is called *night effect*, and becomes appreciable (above 1°) at ranges of about 100 miles by day and 25 miles by night. It follows,

therefore, that bearings taken at greater ranges are subject to this variable night effect and they should be treated with extreme caution if used in navigation.

D/F bearings taken on short waves should not be used in navigation owing to the large errors to which they are liable. The D/F calibration report should be consulted about the limit of frequency which it is permissible to use.

METHODS OF FIXING BY W/T—D/F

Position-finding by means of wireless telegraphy is now of great importance. There are two main methods in use. In the first the bearing of a ship is obtained from one or more directional receiving sets ashore and communicated to the ship. In the second the bearing of a shore station is obtained by directional receiving sets carried in the ship.

A bearing obtained from either of these methods gives a position line. The position of a ship may therefore be fixed by :

1. simultaneous bearings of the ship taken by shore stations or by a ship the position of which is known.

2. bearings of different shore stations or ships the positions of which are known, taken by the ship, the bearings being plotted as a running fix.

3. a bearing of, or from, a shore station, or a ship, the position of which is known, combined with an astronomical observation.

A running fix of the ship can be found from bearings of, or from, a single station or ship, with a time interval between them. The ship's run is known and the first bearing (position line) is transferred in the normal way.

FIXING BY W/T—D/F BEARINGS TAKEN FROM SHORE STATIONS

Around the coasts of most maritime countries are a number of wireless telegraphy stations fitted with directional receiving sets and known as W/T—D/F stations.

The procedure varies to some extent for the different stations, and full details are given in the *Admiralty List of Wireless Signals*.

Generally, a ship requiring a bearing calls up the selected station ; the station directs the ship to transmit her call sign, and at the end of this transmission signals the true bearing of the ship from the station.

In some localities several stations are linked by special telegraph cables into a group, and will take simultaneous bearings of the ship if asked to do so. These bearings are then transmitted to the ship by one station, known as the Control Station, which may or may not be a D/F Station itself.

It is impossible for some stations to distinguish between a

bearing and its reciprocal. If a bearing is received which is considered to be the reciprocal, it cannot be plotted as such because the calibration error applied by the station to the bearing observed is probably different from the calibration error which would be applied to the reciprocal.

The accuracy of bearings depends on several conditions, but as a general rule, when within the sector over which the station is designed to work, bearings can be relied upon to within 2°. In the details of W/T—D/F stations given in the *Admiralty List of Wireless Signals*, Volume I, there is frequently a heading entitled 'Good Bearings'. Particular attention should be paid to this information.

If, however, the bearings from three stations are used and the resulting cocked hat is small, considerable reliance may be placed on the fix obtained.

Large errors have been found when bearings cut the coastline at an oblique angle.

If bearings are signalled as 'approximate' or 'second class' they should be used with great caution as large errors may exist.

The advantages of this method over the method whereby the ship takes the bearing, are as follows:

1. No direction finding set is required in the ship.
2. No special skill is required from the operator in the ship, the bearing being determined by the personnel in the shore station, who are always carrying out these operations. Personal error is thus much reduced.
3. The stations being fixed in position, the instruments of land stations are less liable to derangement than are the D/F sets fitted in ships.

The disadvantages are that the ship has to make a W/T signal. It is always desirable to reduce signalling as much as possible even in peace time, and in war time it is imperative to do so because, by the act of signalling, the ship may disclose her presence if not her position to the enemy.

FIXING BY W/T—D/F BEARINGS TAKEN FROM THE SHIP

A ship's wireless direction-finder, if properly calibrated, is an effective aid to navigation because with it a navigator can obtain bearings of W/T stations or ships whose exact geographical positions are known. A list of these stations is given in the *Admiralty List of Wireless Signals*. They will transmit on request so that bearings can be taken of them.

CHOOSING STATIONS

1. Choose coast stations in preference to inland stations because hills and mountains affect the path of the wave.
2 Choose stations near to the ship, under 40 miles if possible.

3. Use beacon stations which transmit regular signals specially designed to assist the ship in taking the bearing.

4. Use stations from which the W/T wave will not run close to the coastline.

D/F INSTALLATIONS ON BOARD H.M. SHIPS

The D/F installation in a ship can be compared with a magnetic compass. Each is influenced by the metal of the ship and deviations are caused.

The passage of the W/T wave through the metal of a ship sets up subsidiary fields and causes an apparent deviation of the wireless wave when it reaches the receiver.

This deviation can be divided into two parts:

1. deviation corrected electrically during calibration, that is, a quadrantal error, zero with the wave ahead, abeam and astern, maximum on the bows and quarters.

2. deviation uncorrected electrically during calibration but allowed for either by a mechanical cam or by a correction curve.

Suspected Errors. The following questions should be asked if it is suspected that the D/F set is giving incorrect results.

1. Have standard tests for the outfit been carried out recently?

2. Have there been any structural alterations or new aerials set up since the last calibration?

3. Were there any temporary alterations, such as the unshipping of a stay or the working of a nearby derrick when bearings were being taken?

4. Was the gyro repeater reading the correct direction of the ship's head?

5. Was there any indication of indirect ray (night effect)?

6. What was the class of bearing?

CALIBRATION

During calibration the ship takes up a position 3 to 5 miles from a shore transmitting station, placing herself clear of intervening or adjacent land, and carries out the following procedure.

1. The transmitting station is brought to bear right ahead. There will then be a pause while adjustments are made to the cam corrector. When these have been completed the ship is slowly turned through 360° at not more than 6° a minute in order to obtain a correction curve. Direct comparisons of the visual and wireless bearings are made at the rate of about two a minute, that is, about every 3° of swing.

2. The ship is then steadied on red or green 45° and on the quarter bearings, if time permits, and observations are taken of

the maximum quadrantal error. If unexpected values are obtained the first operation will have to be repeated.

NOTE. Although correction for the greater portion of the deviation can be applied by a standard cam, where the highest accuracy is required, as for instance in navigation, the correction should be made from the correction curve and the cam reading should be disregarded.

The above procedure is for calibrating a set fitted with rotating coils. The detail varies slightly with various systems.

Occasions when Calibration is necessary.

1. When a new set has been fitted.
2. When any alteration is made to the present set.
3. After any structural alterations liable to upset the installation, as, for instance, fitting stays or catapults.
4. When results obtained from the set have been found to have an error.

Application for Calibration. If for any of the above reasons it is desired to have the D/F installation calibrated, the following information should be forwarded:

1. the date and time it is required to calibrate.
2. details of the faults found or suspected.

It should be sent to:

(*a*) H.M. Signal School, Portsmouth, for ships in home waters;
(*b*) the Squadron Wireless Officer, for ships abroad:

This information should be sent at least 10 *days beforehand.*

Swinging for Calibration. The swing will be carried out by a representative of either H.M. Signal School or the Fleet Wireless Officer and will take approximately four hours. The following points should be noted.

1. The swing must take place in daylight and not within half an hour of sunrise or sunset.
2. Guns, turrets, derricks, catapults, should be in their normal cruising position.
3. Communications between the bridge and the D/F set should be tested beforehand.

After Calibration.

1. The position and dimensions of the D/F aerials must on no account be changed.
2. Additional aerials, either for the ship sets or for private reception, must not be set up in the vicinity of D/F aerials.

CONVERGENCY

Since meridians on the Earth's surface are not parallel but converge towards the poles, it follows that the track of a wireless wave, being a great circle, intersects meridians at a varying

angle. A full description of this theory is given in Volume III of this Manual.

The difference in the angles formed by the intersection of a great circle with two meridians is known as the *convergency of the meridians* or simply the *convergency*.

TRUE AND MERCATORIAL BEARINGS

Meridians on a Mercator's chart being represented by parallel lines, it follows that the true bearing of the ship from the station, or *vice versa*, cannot be represented by a straight line joining the two positions, the straight line joining them being the mercatorial bearing, which differs from the true bearing by plus or minus half the convergency. As it is this mercatorial bearing that is required, all that is necessary when the true bearing is obtained from a D/F station is to add or subtract from it half the convergency and lay off this bearing from the station.

TO FIND THE CONVERGENCY AND HALF-CONVERGENCY

The convergency can be found by the following methods:

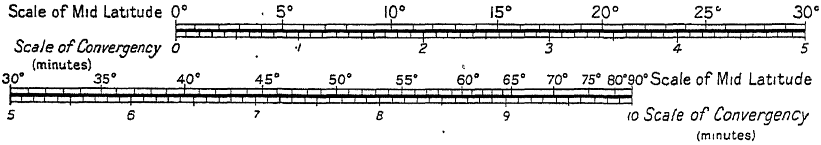
1. By calculation from the formula:

Convergency in minutes=difference of longitude in minutes $\times$ sin middle latitude.

2. By the traverse table: enter the d'long as the distance and the middle latitude as the course; the resulting departure is the convergency in minutes.

3. From the convergency scale below, which is also found in the *Admiralty List of Wireless Signals*.

Scales for obtaining the Convergency for 10′ Diff. Longitude in different Latitudes



Example. Mid lat. 50° 30′, d'long 282′. Find the convergency. Under 50° 30′ on the middle-latitude scale, read 7·7 on the scale of convergency. This, multiplied by 28·2, gives the convergency as 217′.

It must be remembered, however, that it is the half-convergency which has to be applied to the true bearings.

The Half-Convergency can be found direct from the D/F bearing conversion table which is given in the *Admiralty List of Wireless Signals*, Volume II.

SIGN OF THE HALF-CONVERGENCY

If the bearings are always measured clockwise in degrees 000° (north) to 360°, the sign of the half-convergency can be simply determined.

In north latitude when the vessel is	*east* / *west*	of the D/F station the correction is	*added* / *subtracted*
In south latitude when the vessel is	*east* / *west*	of the D/F station the correction is	*subtracted* / *added*

Should the bearing be observed from the ship, the sign of the correction given above is reversed. When the line through the station derived from the observed bearing of the station is plotted, the corrected bearing is increased by 180°. It may be noted here as a precaution that the application of half the convergency corrects the bearing for distortion due to the construction of charts on the Mercator projection, and has no relation whatever to the error of calibration.

When the W/T station and the ship are on opposite sides of the equator, the middle-latitude factor is very small and the convergency is then negligible. All great circles in the neighbourhood of the equator appear on the chart as straight lines and the convergency correction as described above is unnecessary.

Should the estimated position differ much from the true position as found by the first plot, then a retrial, using the new position, is necessary to obtain the proper correction.

Example I. Fixing the ship's position by simultaneous bearings of the ship taken by two shore stations.

In figure 49, a ship in E.P. position lat. 48° 45′ N., long. 25° 30′ W. obtains D/F bearings from Malin Head 244¾° and from Ushant 277½°. What is her position ?

Malin Head ..	lat. 55° 22′ N.	long.	7° 20½′ W.
E.P.	„ 48° 45′ N.	„	25° 30′ W.
mid lat. ..	52° 03′ N.	d'long	1089·5′

Convergency = 1089·5 × sin 52° = 859′
half-convergency = 7° 09′

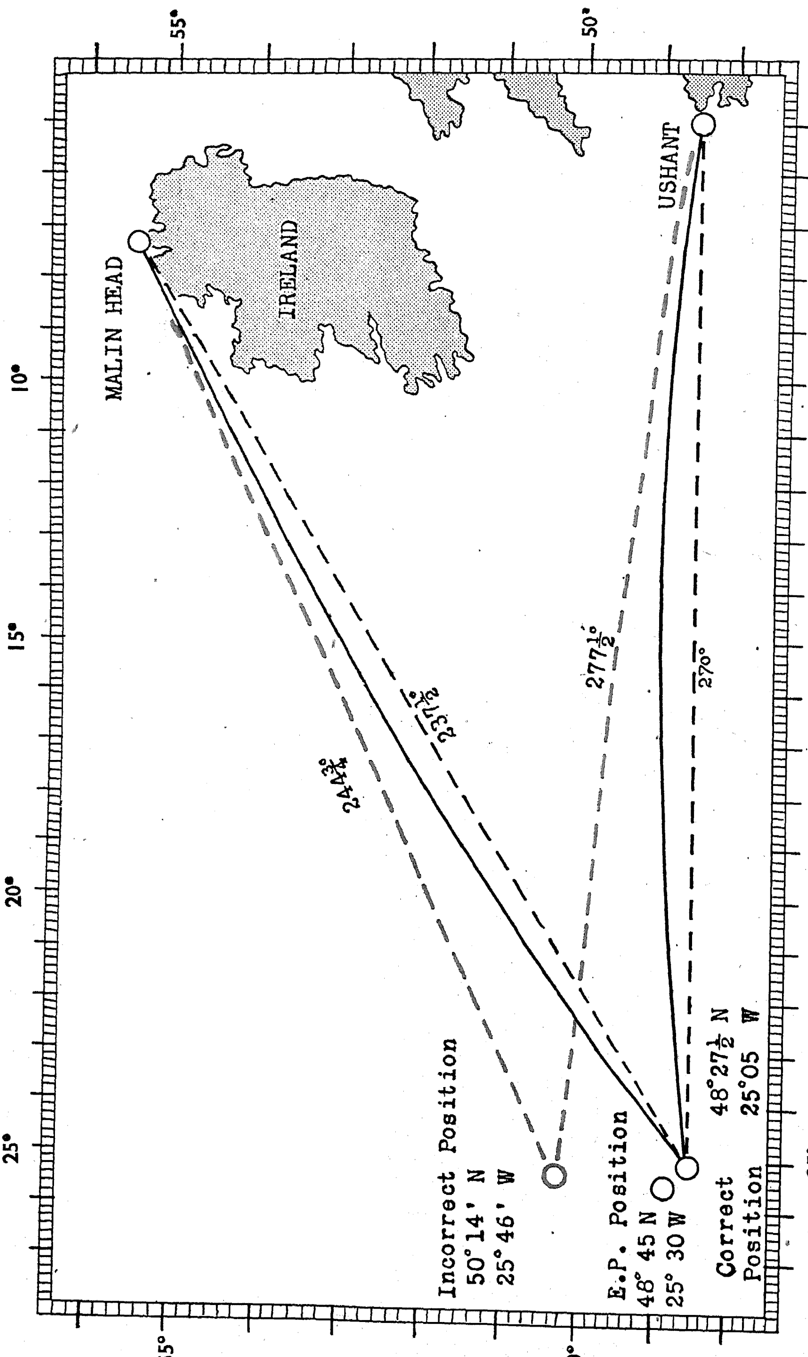
As the ship is west of the station the half-convergency *must be subtracted from* the true bearing signalled.

Therefore the mercatorial bearing will be 237½°.

Similarly with Ushant.

E.P.	lat. 48° 45′ N.	long.	25° 30′ W.
Ushant	„ 48° 27½′ N.	„	5° 07′ W.
mid lat. ..	48° 36′ N.	d'long	1223

Convergency = 1223 × sin 48° 36′ = 918′
half-convergency = 7° 40′



55°
50°
5°
10°
15°
20°
25°
MALIN HEAD
IRELAND
USHANT
244¾°
237½°
277½°
270°
Incorrect Position
50°14' N
25°46' W
E.P. Position
48°45 N
25°30 W
Correct Position
48°27½ N
25°05 W

FIGURE 49.

As the ship is west of the station the half-convergency *must be subtracted from* the true bearing signalled.

The mercatorial bearing is therefore 270°.

When the bearings 237½° and 270° are laid off on the chart from Malin Head and Ushant, a fix is obtained in lat. 48° 27½′ N., long 25° 05′ W., which is the ship's position.

NOTE.—The following points should be borne in mind:

1. In plotting the positions the largest-scale chart available that takes in the whole area, should be used.
2. The solid lines are the great circles passing through Malin Head and ship's position and Ushant and ship's position.
3. The red lines are the true bearings laid off as signalled, their intersection being in lat. 50° 14′ N., long. 25° 46′ W., or approximately 110′ from the correct position.
4. As the true position of the ship should have been used to obtain the half-convergency, the quantity found is not correct, but it could be re-calculated using the latitude and longitude of the approximate fix and a more correct value found. This, however, is necessary only if the error in the ship's assumed position is very great.

Accuracy of this Method of Plotting. Although this method is not rigidly accurate, it can be used for all practical purposes up to a range of 100 miles, and a very close approximation found to the position lines upon which the ship is at the moment the stations receive her signals.

Example II. Fixing the ship's position by astronomical observation and a D/F bearing of a W/T fog signal taken by the ship.

Course 160°, speed 12 knots. Tidal stream between 0650 and 0850 setting 140°—2½ knots.

At 0650 in E.P. position 56° 40′ N., 1° 00′W. a Sun sight gave an intercept of 4′ towards. Sun's true bearing 100°.

At 0850 a D/F bearing of 276° was obtained by the ship of May Island W/T Fog Signal. (May Island W/T Fog Signal sends 'clear weather' transmission twice every hour.) What was the ship's position at 0850 ?

May Island ..	lat. 56° 11′ N.	long. 2° 33′ W.
0850 E.P.	56° 13′ N.	„ 0° 32′ W.
mid lat. ..	56° 12′ N.	d'long 121′

convergency = 121 sin 56° 12′

= 100′

half-convergency = 50′

As the ship is east of the station the half-convergency must be subtracted from the true bearing found. Therefore the mercatorial bearing to be plotted will be 275¼°.

From plotting on the chart as shown in figure 50 the ship's position will be found to be lat. 56° 05′ N., long. 0° 35′ W.

The mathematical explanation of the above examples is given in Volume III.

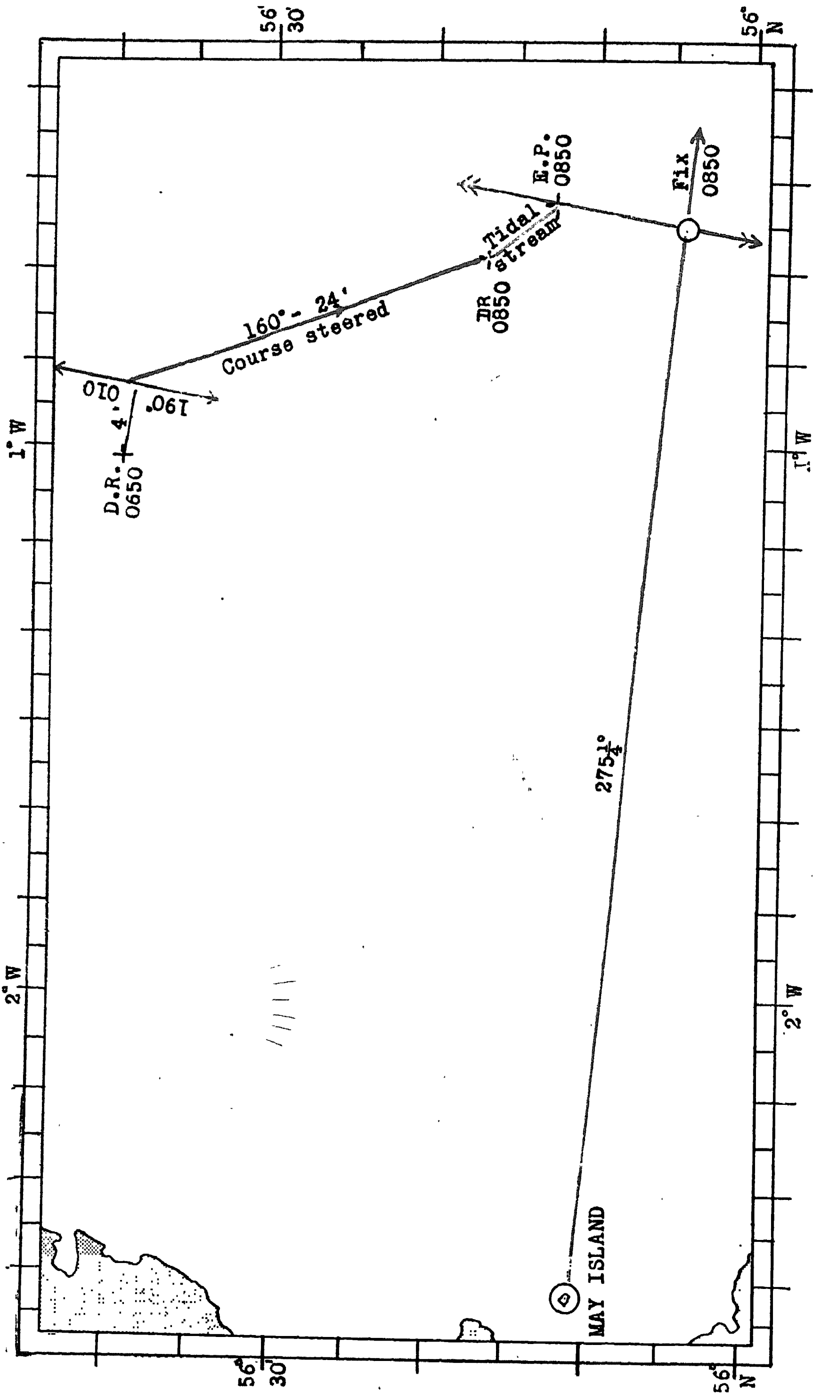

56° 30'
56° N
1° W
2° W
D.R. 0650
4'
010
190°
160° - 24'
Course steered
DR 0850
Tidal stream
E.P. 0850
Fix 0850
275¼°
MAY ISLAND

FIGURE 50.

CHAPTER VI

RULE OF THE ROAD

The articles and rules referred to in this Chapter are quoted from the *International Regulations for Preventing Collisions at Sea,* formulated at the International Convention for Safety of Life at Sea, 1929.

The paragraphs in italics have not yet been ratified (1936).

PRELIMINARY

Definitions. These Rules shall be followed by all vessels upon the high seas and in all waters connected therewith, navigable by sea-going vessels.

In the following Rules every steam-vessel which is under sail and not under steam is to be considered a sailing vessel, and every vessel under steam, whether under sail or not, is to be considered a steam-vessel.

The word " steam-vessel " shall include any vessel propelled by machinery.

The term " under steam " shall mean under any mechanical power.

A vessel is " under way " within the meaning of these Rules when she is not at anchor, or made fast to the shore, or aground.

The length of a vessel shall be deemed to be the length appearing in her certificate of registry.

RULES CONCERNING LIGHTS, ETC.

Lights. The word " visible " in these Rules, when applied to lights, shall mean visible on a dark night with a clear atmosphere.

Article 1. The Rules concerning lights shall be complied with in all weathers, from sunset to sunrise, and during such time no other lights which may be mistaken for the prescribed lights shall be exhibited.

Article 2. Lights for Steamships. A steam-vessel when under way shall carry :

(*a*) On or in front of the foremast, or if a vessel without a foremast, then in the fore part of the vessel, at a height above the hull of not less than 20 feet, and if the breadth of the vessel exceeds 20 feet, then at a height above the hull not less than such breadth, so, however, that the light need not be carried at a greater height above the hull than 40 feet, a bright white light, so constructed as to show an

unbroken light over an arc of the horizon of 20 points of the compass, so fixed as to throw the light 10 points on each side of the vessel, viz., from right ahead to 2 points abaft the beam on either side, and of such a character as to be visible at a distance of at least 5 miles.

(*b*) *Either forward or aft of the white light mentioned in sub-section* (*a*) *a second white light similar in construction and character to that light.*

Vessels of less than 150 feet in length shall not be required to carry this second white light, but may do so.

(*c*) These two white lights shall be so placed in a line with the keel that one shall be at least 15 feet higher than the other and in such a position that the lower light shall be forward of the upper one, and higher than the lights mentioned in Article 2 (*d*) and (*e*). The vertical distance between the two white lights shall be less than the horizontal distance.

(*d*) On the starboard side, a green light so constructed as to show an unbroken light over an arc of the horizon of 10 points of the compass, so fixed as to throw the light from right ahead to 2 points abaft the beam on the starboard side, and of such character as to be visible at a distance of at least 2 miles.

(*e*) On the port side, a red light so constructed as to show an unbroken light over an arc of the horizon of 10 points of the compass, so fixed as to throw the light from right ahead to 2 points abaft the beam on the port side, and of such character as to be visible at a distance of at least 2 miles.

(*f*) The said green and red side-lights shall be fitted with inboard screens projecting at least 3 feet forward from the light, so as to prevent these lights from being seen across the bow.

Article 3. Lights for Ships Towing. A steam-vessel when towing another vessel shall, in addition to her side-lights, carry two bright white lights in a vertical line one over the other, not less than 6 feet apart, and when towing more than one vessel, shall carry an additional bright white light 6 feet above or below such lights, if the length of tow, measuring from the stern of the towing vessel to the stern of the last vessel towed, exceeds 600 feet. Each of these lights shall be of the same construction and character, and shall be carried in the same position as the white light mentioned in Article 2 (*a*) except the additional light, which may be carried at a height of not less than 14 feet above the hull.

The vessel towing and the vessels towed, except the last vessel of the tow, may carry in lieu of the light required in Article 10, *a small white light abaft the funnel or aftermast, for the tow to steer by, but such light shall not be visible forward of the beam.*

Article 4. Special Lights for Ships not Under Command and for Telegraph Ships.

(*a*) A vessel which from any accident is not under command shall carry at the same height as the white light mentioned in

Article 2 (*a*), where they can best be seen, and, if a steam-vessel, in lieu of that light, two red lights, in a vertical line one over the other, not less than 6 feet apart, and of such character as to be visible all round the horizon at a distance of at least 2 miles; and shall by day carry in a vertical line one over the other not less than 6 feet apart, where they can best be seen, two black balls or shapes each 2 feet in diameter.

(*b*) A vessel employed in laying or in picking up a telegraph cable shall carry in the same position as the white light mentioned in Article 2 (*a*) and, if a steam-vessel, in lieu of that light, three lights in a vertical line one over the other, not less than 6 feet apart. The highest and lowest of these lights shall be red and the middle light shall be white, and they shall be of such character as to be visible all round the horizon at a distance of at least 2 miles. By day she shall carry in a vertical line one over the other, not less than 6 feet apart, where they can best be seen, three shapes not less than 2 feet in diameter, of which the highest and the lowest shall be globular in shape and red in colour and the middle one diamond in shape and white.

(*c*) The vessels referred to in this Article when not making way through the water shall not carry the side-lights, but when making way shall carry them.

(*d*) The lights and shapes required to be shown by this Article are to be taken by other vessels as signals that the vessel showing them is not under command and cannot therefore get out of the way.

These signals are not signals of vessels in distress and requiring assistance. Such signals are contained in Article 31.

NOTE: Attention is drawn to the following clauses of the *Submarine Telegraph Act*, 1885:

"(*a*) When a ship engaged in repairing a cable exhibits the signals (specified in Art. 4 (*b*) of the *Regulations for Preventing Collisions*), other vessels which see them, or are able to see them, shall withdraw to or keep beyond a distance of one nautical mile at least from the ship in question, so as not to interfere with her operations."

"(*b*) Vessels which see, or are able to see, the buoys showing the position of the cable when the latter is being laid, is out of order, or is broken, shall keep beyond a distance of one quarter of a nautical mile at least from the said buoys."

Article 5. Lights for Sailing Ships or Vessels being Towed. A sailing vessel under way, and any vessel being towed, shall carry the same lights as are prescribed by Article 2 for a steam-vessel under way, with the exception of the white lights mentioned therein, which they shall never carry.

Article 6. Exceptional Lights for Small Vessels. Whenever, as in the case of small vessels under way during bad weather, the green and red side-lights cannot be fixed, these lights shall be kept at hand lighted and ready for use; and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient

time to prevent collision, in such manner as to make them most visible, and so that the green light shall not be seen on the port side nor the red light on the starboard side, nor, if practicable, more than 2 points abaft the beam on their respective sides.

To make the use of these portable lights more certain and easy, the lanterns containing them shall each be painted outside with the colour of the light they respectively contain, and shall be provided with proper screens.

Article 7. Lights for Small Craft and Rowing Boats. Steam-vessels of less than 40, and vessels under oars or sails of less than 20, tons gross tonnage, respectively, and rowing boats, when under way, shall not be obliged to carry the lights mentioned in Article 2 (*a*), (*d*) and (*e*), but if they do not carry them, they shall be provided with the following lights :

(1) Steam-vessels of less than 40 tons shall carry :

(*a*) In the forepart of the vessel, or on or in front of the funnel, where it can best be seen, and at a height above the gunwhale of not less than 9 feet, a bright white light constructed and fixed as prescribed in Article 2 (*a*), and of such a character as to be visible at a distance of at least 2 miles.

(*b*) Green and red side-lights constructed and fixed as prescribed in Article 2 (*d*) and (*e*), and of such a character as to be visible at a distance of at least 1 mile, or a combined lantern showing a green light and a red light from right ahead to 2 points abaft the beam on their respective sides. Such lantern shall be carried not less than 3 feet below the white light.

(2) Small steamboats, such as are carried by sea-going vessels, may carry the white light at a less height than 9 feet above the gunwhale, but it shall be carried above the combined lantern mentioned in sub-division (1) (*b*).

(3) Vessels under oars or sails, of less than 20 tons, shall have ready at hand a lantern with a green glass on one side and a red glass at the other, which, on the approach of or to other vessels, shall be exhibited in sufficient time to prevent collision, so that the green light shall not be seen on the port side nor the red light on the starboard side.

(4) Rowing boats, whether under oars or sail, shall have ready at hand a lantern showing a white light, which shall be temporarily exhibited in sufficient time to prevent collision.

The vessels referred to in this Article shall not be obliged to carry the lights prescribed by Article 4 (*a*) and Article 11, last paragraph.

Article 8. Pilot-Vessels. When engaged on their station on pilotage duty, shall not show the lights required for other vessels, but shall carry a white light at the masthead, visible all round the

horizon, and shall also exhibit a flare-up light or flare-up lights at short intervals, which shall never exceed 15 minutes.

On the near approach of or to other vessels they shall have their side-lights lighted, ready for use, and shall flash or show them at short intervals, to indicate the direction in which they are heading, but the green light shall not be shown on the port side, nor the red light on the starboard side.

A pilot-vessel of such a class as to be obliged to go alongside a vessel to put a pilot on board, may show the white light instead of carrying it at the masthead, and may, instead of the coloured lights above mentioned, have at hand ready for use a lantern with a green glass on the one side and a red glass on the other, to be used as prescribed above.

A steam pilot-vessel exclusively employed for the service of pilots licensed or certified by any pilotage authority or the committee of any pilotage district, when engaged on her station on pilotage duty and not at anchor, shall, in addition to the lights required for all pilot boats, carry at a distance of 8 feet below her white masthead light a red light visible all round the horizon and of such a character as to be visible on a dark night with a clear atmosphere at a distance of at least 2 miles, and also the coloured side-lights required to be carried by vessels when under way.

When engaged on her station on pilotage duty and at anchor, she shall carry, in addition to the lights required for all pilot boats, the red light above mentioned, but not the coloured side-lights.

Pilot-vessels, when not engaged on their station on pilotage duty, shall carry lights similar to those of other vessels of their tonnage.

Article 9. Lights for Fishing and Other Open Boats. Fishing vessels and fishing boats, when under way and when not required by this Article to carry or show the lights hereinafter specified, shall carry or show the light prescribed for vessels of their tonnage under way.

(*a*) Open boats, by which it is to be understood boats not protected from the entry of sea-water by means of a continuous deck, when engaged in any fishing at night with outlying tackle extending not more than 150 feet horizontally from the boat into the sea way, shall carry one all-round white light.

Open boats, when fishing at night, with outlying tackle extending more than 150 feet horizontally from the boat into the sea-way shall carry one all-round white light, and in addition, on approaching or being approached by other vessels, shall show a second white light at least 3 feet below the first light and at a horizontal distance of at least 5 feet away from it in the direction in which the outlying tackle is attached.

(*b*) Vessels and boats, except open boats as defined in subdivision (*a*) when fishing with drift-nets, shall, so long as the nets are wholly or partly in the water, carry two white lights where they can best be seen. Such lights shall be placed so that the vertical

distance between them shall be not less than 6 feet and not more than 15 feet, and so that the horizontal distance between them, measured in a line with the keel, shall be not less than 5 feet and not more than 10 feet. The lower of these two lights shall be in the direction of the nets, and both of them shall be of such a character as to show all round the horizon, and to be visible at a distance of not less than 3 miles.

Within the Mediterranean Sea and in the seas bordering the coasts of Japan and Korea, sailing fishing vessels of less than 20 tons gross tonnage shall not be obliged to carry the lower of these two lights; should they, however, not carry it, they shall show in the same position (in the direction of the net or gear) a white light, visible at a distance of not less than one sea mile, on the approach of or to other vessels. (See notes (iii) and (iv).)

(*c*) Vessels and boats, except open boats as defined in sub-division (*a*), when line-fishing with their lines out and attached to or hauling their lines, and when not at anchor or stationary within the meaning of sub-division (*h*), shall carry the same lights as vessels fishing with drift-nets. When shooting lines, or fishing with towing lines, they shall carry the lights prescribed for a steam or sailing vessel under way respectively.

Within the Mediterranean Sea and in the seas bordering the coasts of Japan and Korea, sailing fishing vessels of less than 20 tons gross tonnage shall not be obliged to carry the lower of these two lights; should they, however, not carry it, they shall show in the same position (in the direction of the lines) a white light, visible at a distance of not less than one sea mile on the approach of or to other vessels. (See note (iv).)

(*d*) Vessels when engaged in trawling, by which is meant the dragging of an apparatus along the bottom of the sea:

(1) If steam-vessels, shall carry in the same position as the white light mentioned in Article 2 (*a*) a tricoloured lantern so constructed and fixed as to show a white light from right ahead to two points on each bow, and a green light and a red light over an arc of the horizon from two points on each bow to two points abaft the beam on the starboard and port sides respectively; and not less than 6 nor more than 12 feet below the tricoloured lantern, a white light in a lantern so constructed as to show a clear uniform and unbroken light all round the horizon.

(2) If sailing-vessels, shall carry a white light in a lantern so constructed as to show a clear uniform and unbroken light all round the horizon, and shall also, on the approach of or to other vessels, show, where it can best be seen, a white flare-up light or torch in sufficient time to prevent collision.

All lights mentioned in sub-division (*d*) (1) and (2) shall be visible at a distance of at least 2 miles.

(*e*) Oyster dredgers and other vessels fishing with dredge nets shall carry and show the same lights as trawlers.

(*f*) Fishing vessels and fishing boats may at any time use a flare-up light in addition to the lights which they are by this Article required to carry and show, and they may also use working lights.

(*g*) Every fishing vessel and every fishing boat under 150 feet in length, when at anchor, shall exhibit a white light visible all round the horizon at a distance of at least 1 mile.

Every fishing vessel of 150 feet in length or upwards, when at anchor, shall exhibit a white light visible all round the horizon at a distance of at least 1 mile, and shall exhibit a second light as provided for vessels of such length by Article 11.

Should any such vessel, whether under 150 feet in length or of 150 feet in length or upwards, be attached to a net or other fishing gear she shall, on the approach of other vessels, show an additional white light at least 3 feet below the anchor light, and at a horizontal distance of at least 5 feet away from it in the direction of the net or gear.

(*h*) If a vessel or boat when fishing become stationary in consequence of her gear getting fast to a rock or other obstruction, she shall in daytime haul down the day signal required by subdivision (*k*) ; at night show the light or lights prescribed for a vessel at anchor ; and during fog, mist, falling snow, or heavy rain-storms make the signal prescribed for a vessel at anchor. (See subdivision (*d*) and the last paragraph of Article 15.)

(*i*) In fog, mist, falling snow, or heavy rain-storms, drift-net vessels attached to their nets, and vessels when trawling, dredging or fishing with any kind of drag-net, and vessels line-fishing with their lines out, shall, if of 20 tons gross tonnage or upwards, respectively, at intervals of not more than 1 minute make a blast ; if steam vessels, with the whistle or siren, and if sailing vessels, with the fog-horn ; each blast to be followed by ringing the bell. Fishing vessels and boats of less than 20 tons gross tonnage shall not be obliged to give the above-mentioned signals ; but if they do not, they shall make some other efficient sound signal at intervals of not more than 1 minute.

(*k*) All vessels or boats fishing with nets or lines or trawls, when under way, shall in daytime indicate their occupation to an approaching vessel by displaying a basket or other efficient signal where it can best be seen. If vessels or boats at anchor have their gear out, they shall, on the approach of other vessels, show the same signal on the side on which those vessels can pass.

The vessels required by this Article to carry or show the lights hereinbefore specified, shall not be obliged to carry the lights prescribed by Article 4 (*a*) and the last paragraph of Article 11.

NOTE. (i) This Article does not apply to Chinese or Siamese vessels.

(ii) The expression "Mediterranean Sea" contained in sub-sections (*b*) and (*c*) of this Article includes the Black Sea and the other adjacent inland seas in communication with it.

(iii) Dutch vessels and boats when engaged in the "kol", or hand line, fishing will carry the lights prescribed for vessels fishing with drift-nets.

(iv) Also, as regards Russian vessels, in the seas (excluding the Baltic) bordering the coasts of Russia.

(v) The following has been issued by the Board of Trade:

Notice to Owners and Skippers of Fishing Vessels

Markings and Lighting of Seine Net Fishing Vessels

Certain signals were recently agreed upon by representatives of the Sea Fishing Industry for the use of seine net fishing vessels in order to protect their gear from injury by other vessels. In order to avoid the possibility of confusion it has been found desirable to make certain changes in these signals. In the day signal the black triangle will be replaced by a black cone and the sound signal will be three long and one short blasts on the whistle instead of two long and one short blasts as previously agreed. The revised signals to be used by seine net fishing vessels when actually fishing with seine nets are as follows:

By Day. One Black Ball Basket or Shape carried in the forepart of the vessel as near to the stem as possible, not less than 10 feet above the rail.

One Black Cone carried apex upward on a cross yard arm fixed to the Mizzen Mast on the side from which the net is being operated.

By Night. Three white lights in a triangle of approximately 2½ feet side hung apex upwards from the cross yard on the side of the ship from which the gear is leading. The signal is to be used in conjunction with the side lights when running the gear and without the side lights when hauling the gear. In neither case should the masthead light be shown.

Sound Signal. Three long and one short blasts on the whistle when being approached by other vessels.

When a vessel is at anchor at night and not working gear, the usual anchor lights as prescribed by Article 9 of the Collision Regulations, 1910, will be shown and no other light should be used.

The Board of Trade understand that the owners of British seine net vessels have agreed to use the above signals and that the signals will, in fact, be displayed as indicating that the vessel is at the time fishing with a seine net, in order that other vessels approaching may give the seine net vessel a wide berth.

Article 10. *A vessel when under way shall carry at her stern a white light so constructed, fitted, and screened, that it shall throw an unbroken light over an arc of the horizon of 12 points of the compass, viz., for 6 points from right aft on each side of the vessel, and of such a character as to be visible at a distance of at least 2 miles. Such light shall be carried as nearly as practicable on the same level as the side-lights.*

In small vessels, if it is not possible on account of bad weather or other sufficient cause for this light to be fixed, a light shall be kept at hand lighted and ready for use, and shall, on the approach of an overtaking vessel, be shown in sufficient time to prevent collision. In naval vessels of special construction, in which it is not possible to comply with the provisions of this Article as to the position of lights or their range of visibility, those provisions shall be followed as closely as circumstances will permit.

For vessels engaged in towing, see Article 3, last paragraph.

Article 11. Lights for Ships at Anchor. A vessel under 150 feet in length, when at anchor, shall carry forward, where it can best be seen, but at a height not exceeding 20 feet above the hull, a white light in a lantern so constructed as to show a clear, uniform, and unbroken light visible all round the horizon at a distance of at least 1 mile.

A vessel of 150 feet or upwards in length, when at anchor, shall carry in the forward part of the vessel, at a height of not less than 20, and not exceeding 40 feet above the hull one such light, and at or near the stern of the vessel, and at such a height that it shall be not less than 15 feet lower than the forward light, another such light.

The length of a vessel shall be deemed to be the length appearing in her certificate of registry.

Between sunrise and sunset all vessels when at anchor in or near a fairway shall carry, forward, where it can best be seen, one black ball, 2 feet in diameter.

A vessel aground in or near a fairway shall carry by night the above light or lights and the two red lights prescribed by Article 4 (a), and by day, where they can best be seen, 3 black balls, each 2 feet in diameter, placed in a vertical line one over the other.

Article 12. Flare-up Light or Detonating Signal. Every vessel may, if necessary in order to attract attention, in addition to the lights which she is by these Rules required to carry, show a flare-up light, or use any detonating signal that cannot be mistaken for a distress signal.

Article 13. Proviso as to Lights of Squadrons and Convoys. Nothing in these Rules shall interfere with the operation of any Special Rules made by the Government of any nation with respect to additional station and signal lights for two or more ships-of-war or for vessels sailing under convoy, or with the exhibition of recognition signals adopted by shipowners, which have been authorised by their respective Governments and duly registered and published.

Article 14. *A vessel proceeding under sail when also under steam or other mechanical power shall carry in the daytime, forward, where it can best be seen, one black cone, point upwards, 2 feet in diameter at its base.*

SOUND SIGNALS FOR FOG, ETC.

Article 15. Fog, Mist, Snow Signals. All signals prescribed by this Article for vessels under way shall be given :

(1) By " steam-vessels " on the whistle or siren.

(2) By " sailing vessels and vessels towed " on the fog-horn.

The words " prolonged blast " used in this Article shall mean a blast of from 4 to 6 seconds' duration.

A steam-vessel shall be provided with an efficient whistle or siren sounded by steam or some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog-horn, to be sounded by mechanical means, and also with an efficient bell. A sailing vessel of 20 tons gross tonnage or upwards shall be provided with a similar fog-horn and bell.

In fog, mist, falling snow, or heavy rain-storms, whether by day or night, the signals described in this Article shall be used as follows, viz. :

(*a*) A steam-vessel having way upon her, shall sound, at intervals of not more than two minutes, a prolonged blast.

(*b*) A steam-vessel under way, but stopped and having no way upon her, shall sound, at intervals of not more than 2 minutes, two prolonged blasts, with an interval of about 1 second between them.

(*c*) A sailing vessel under way shall sound, at intervals of not more than 1 minute, when on the starboard tack one blast, when on the port tack two blasts in succession, and when with the wind abaft the beam three blasts in succession.

(*d*) A vessel, when at anchor, shall at intervals of not more than 1 minute, ring the bell rapidly for about 5 seconds.

In vessels of more than 350 feet in length the bell shall be sounded in the forepart of the vessel, and, in addition, there shall be sounded in the afterpart of the vessel, at intervals of not more than 1 minute, a gong or other instrument, the tone of which cannot be confused with the ringing of the bell.

(*e*) A vessel when towing, a vessel employed in laying or in picking up a telegraph cable, and a vessel under way, which is unable to get out of the way of an approaching vessel through being not under command, or unable to manœuvre as required by these Rules, shall, instead of the signals prescribed in sub-divisions (*a*) and (*c*) of this Article, at intervals of not more than 2 minutes, sound three blasts in succession, viz., one prolonged blast followed by two short blasts.

A vessel towed, or if more than one vessel is towed, the last vessel of the tow, shall, at intervals of not more than 2 minutes, sound 4 blasts in succession, viz., 1 prolonged blast followed by 3 short blasts, provided that this signal is not required when it is impossible to keep the vessel manned.

When practicable, the vessel towed shall make this signal immediately after the signal made by the towing vessel.

(*f*) *A vessel aground in or near a fairway shall give the signal prescribed in paragraph* (*d*), *and shall, in addition, give 3 separate and distinct strokes on the bell immediately preceding and following each such signal.*

Sailing vessels and boats of less than 20 tons gross tonnage shall not be obliged to give the above-mentioned signals, but if they do not, they shall make some other efficient sound-signals at intervals of not more than one minute.

NOTE. (i) In all cases where the Rules require a bell to be used, a drum may be substituted on board Turkish vessels, or a gong where such articles are used on board small sea-going vessels.

(ii) Dutch steam pilot-vessels, when engaged on their station on pilotage duty in fog, mist, falling snow, or heavy rainstorms, are required to make, at intervals of 2 minutes at most, one long blast with the siren, followed after 1 second by a long blast with the steam whistle, and again after 1 second by a long blast on the siren. When not engaged on their station on pilotage duty, they make the same signals as other steamships.

SPEED OF SHIPS TO BE MODERATE IN FOG, ETC.

Article 16. Speed in Fog, etc. Every vessel shall, in a fog, mist, falling snow, or heavy rainstorms, go at a moderate speed, having careful regard to the existing circumstances and conditions.

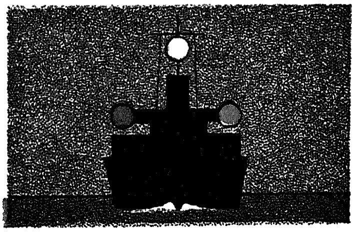
A steam-vessel hearing, apparently forward of her beam, the fog-signal of a vessel the position of which is not ascertained, shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

LIGHTS AND SIGNALS

The coloured illustrations in the pages that complete this chapter show the lights and signals described in the Articles so far referred to and others that will be quoted, as they would be seen from the bridge of a nearby vessel. These signals include both the day signals ordered to be carried by various vessels and aircraft in particular circumstances, and the special signals carried by certain vessels, such as trawlers engaged in sweeping by day or night. A brief description is given against such illustration, but the illustration itself should be studied in conjunction with the relevant Article, the number of which is given.

As depicted in the illustrations, the colours of the lights and the shapes that are hoisted are necessarily more prominent than they are in reality. To that extent the illustrations are diagrammatic, and this fact should be borne in mind.

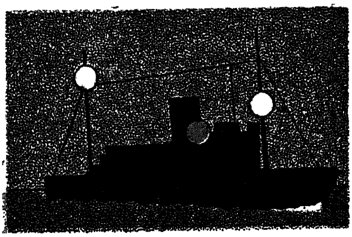
LIGHTS OF VESSELS AS SEEN FROM THE BRIDGE



A Steam Vessel under Way, Bows on

Showing masthead lights, and port and starboard side lights. Masthead lights visible 5 miles; side lights visible 2 miles. Similar lights are shown by **A Steam Fishing Vessel, Shooting or Towing Lines.**

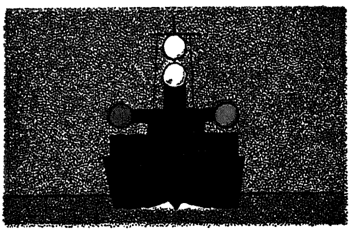
(Articles 2 and 9.)



A Steam Vessel Under Way

Showing the usual masthead light and side light and, an additional masthead light aft. Masthead lights visible 5 miles, side lights visible 2 miles.

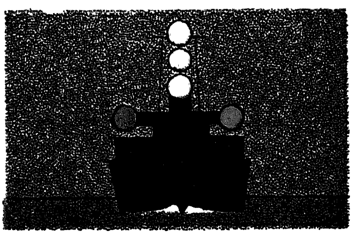
(Article 2.)



A Steam Vessel Towing another Vessel, Bows on

Showing two masthead lights, vertical, also port and starboard side lights. Masthead lights visible 5 miles; side lights visible 2 miles.

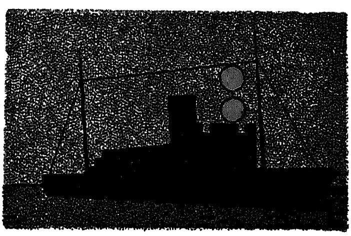
(Article 3.)



A Steam Vessel Towing more than one Vessels, Bows on, the Length of Tow Exceeding 600 feet

Showing three masthead lights, vertical, also port and starboard side lights.

(Article 3.)

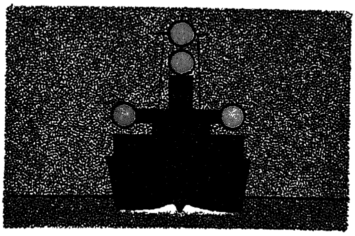


A Vessel not under Command

Showing two red all-round lights, vertical, visible 2 miles.

(Article 4.)

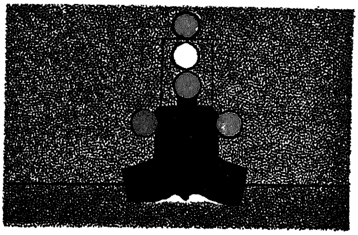
LIGHTS OF VESSELS AS SEEN FROM THE BRIDGE—*continued*



A Vessel not under Command, making way through the Water, Bows on

Showing two red all-round lights, vertical, and the usual side lights. All lights visible 2 miles.

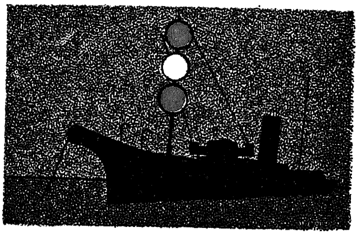
(Article 4.)



A Vessel Employed Repairing or Laying Telegraph Cables, making way through the Water, Bows on

Showing three lights, red-white-red, vertical, also port and starboard side lights. All lights visible 2 miles.

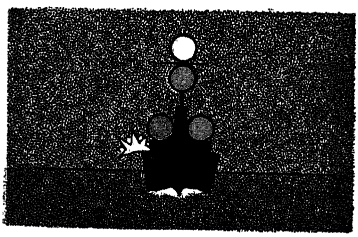
(Article 4.)



A Vessel Employed Repairing or Laying Telegraph Cables but not making way through the Water

Showing three lights, red-white-red, vertical. Visible 2 miles.

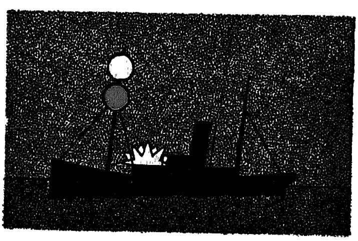
(Article 4.)



A Steam Pilot Vessel under Way, Bows on

Showing the usual side lights and a red all-round light under the usual masthead light. These vessels also show a flare at short intervals. Masthead light visible 5 miles and the other lights visible 2 miles.

(Article 8.)



A Steam Pilot Vessel at Anchor

Showing a red all-round light under the usual masthead light. These vessels also show a flare at short intervals. Masthead light visible 5 miles and the red light visible 2 miles.

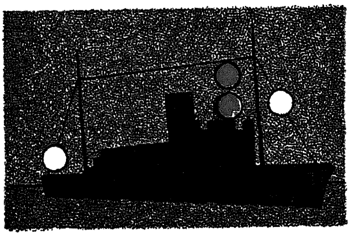
(Article 8.)

LIGHTS OF VESSELS AS SEEN FROM THE BRIDGE—*continued*

A Small Steam Vessel, Gross Tonnage under 40 tons, Bows on

Showing a white light over a combined red and green lantern. White light visible 2 miles and the lantern visible 1 mile.

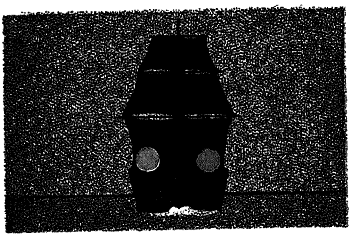
(Article 7.)



A Vessel Aground, In or Near a Fairway

Showing two red all-round lights and the usual anchor light. If the vessel is over 150 feet long she carries two anchor lights. Red lights visible 2 miles and anchor lights visible 1 mile.

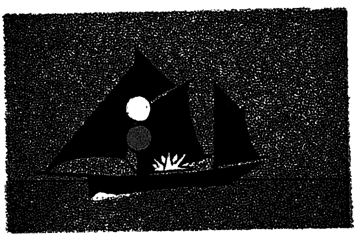
(Articles 4a and 11.)



A Sailing Vessel under Way, or any Vessel being Towed, Bows on

Showing the usual side lights. Visible 2 miles. These lights are also carried by **A Fishing Vessel Shooting or Towing Lines.**

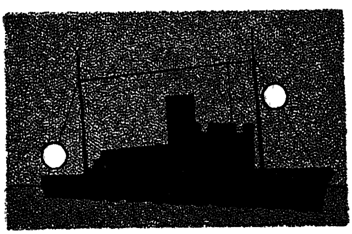
(Articles 5 and 9.)



A Sailing Pilot Vessel on her Station

Showing an all-round masthead light and a flare. The flare is shown at short intervals, not exceeding ten minutes. When under way the usual side lights are shown. These lights are also carried by **Sailing Trawlers,** but they only show the flare in sufficient time to avoid a collision.

(Articles 8 and 9.)



A Vessel, over 150 feet long, at Anchor

Showing two all-round white lights. The high light forward and the low light aft. Visible 1 mile.

(Article 11.)

LIGHTS OF VESSELS AS SEEN FROM THE BRIDGE—*continued*

A Steam Trawler under Way

Carries a tricolour lantern showing a white light from right ahead to two points on each bow and a red light and a green light over an arc of the horizon from two points on each bow to two points abaft the beam on the port and starboard sides respectively Below the lantern she carries an all-round white light. Both lights visible 2 miles.

(Article 9.)

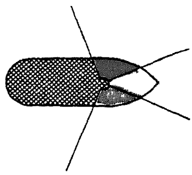


Figure 1 shows the arcs of the tricolour lantern.

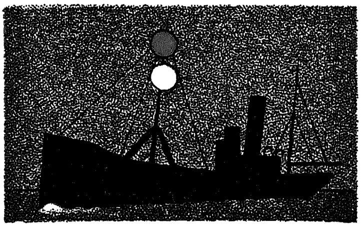


Figure 2 shows a trawler crossing from starboard to port.

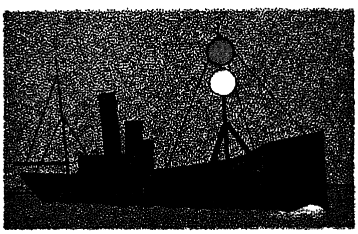
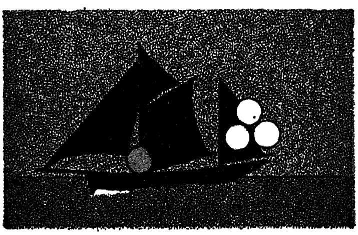


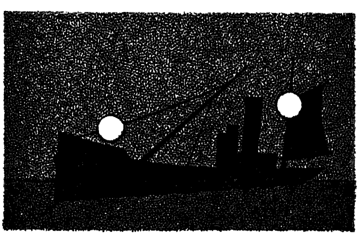
Figure 3 shows a trawler crossing from port to starboard.



A Seine Net Fishing Vessel

Shows three white lights, apex up, at yardarm. Side lights are shown when the gear is run. When approached by other ships, seine net vessels sound ▬ ▬ ▬ ▪ on the whistle.

(Article 9.)

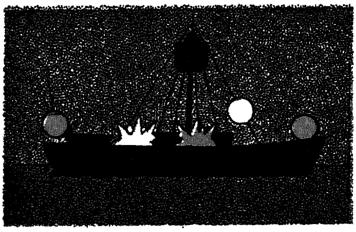


1. **A Drift Net Fishing Vessel with Nets in the Water**
2. **An Open Boat with Fishing Gear Extending more than 150 feet**
3. **A Fishing Vessel under 150 feet long, at Anchor with Fishing Gear Down**

Showing two all-round white lights, the lower light indicating the direction of the fishing gear.

(Article 9.)

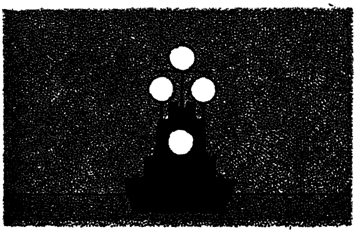
SPECIAL SIGNALS AS SEEN FROM THE BRIDGE

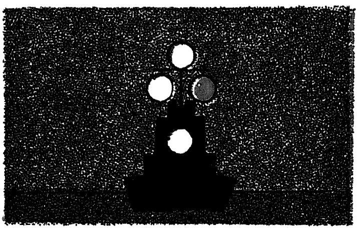


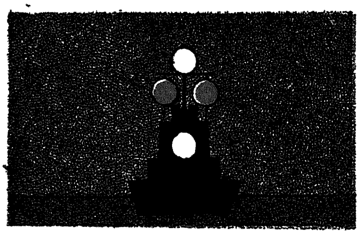
A Light Vessel not in Proper Position

Showing an all-round red light at each end of the vessel. Red and white flares are shown, simultaneously, every fifteen minutes. If it is not possible to use flares, a red light and a white light are shown simultaneously.

NOTE. *By day.* Two black balls, one forward and one aft, and the international signal PC, are hoisted. The normal day mark is not shown.







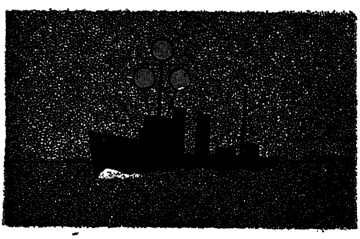
Lights Shown by Dredgers Working in Dockyard Ports

Figure 1 indicates 'Clear both sides'.

Figure 2 indicates 'Do not pass on the side of the red light'.

Figure 3 indicates 'Foul both sides'.

Anchor lights are shown in addition to the other lights. During daylight, dredgers carry black balls in place of the white lights and red flags in place of the red lights.



Lights Shown by Vessels Employed in Sweeping

Figure 1 shows lights carried by a vessel towing a sweep. These vessels should not be approached within 900^x.

During daylight, black balls take the place of the green lights. The green light or the black ball on the yardarm indicates the side on which the sweep is working.

SPECIAL SIGNALS AS SEEN FROM THE BRIDGE—*continued*

Lights Shown by Vessels Employed in Sweeping—*continued*

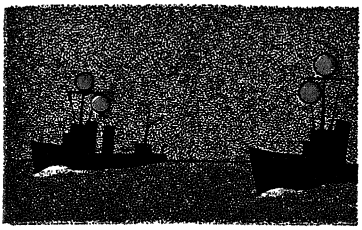
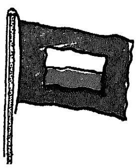


Figure 2 shows lights carried by vessels working in pairs. Ships should not pass between, or cross astern within 400ˣ of vessels working in pairs.

During daylight, black balls take the place of the green lights. The green lights or the black ball on the yardarm indicates the side on which the sweep is working.

Examination Service



The examination service flag is flown by day and the following signals are used to indicate if the port is open or closed.

Port Closed. By day: 3 red balls in a vertical line.
By night: 3 red lights in a vertical line.

Port Open. By day: No signal.
By night: 3 white lights in a vertical line.

NOTES ON LIGHTS SEEN FROM THE BRIDGE AT SEA

A Single White Light may indicate:

1. *a steamship* approaching bows on, the side lights of which are out of visibility range.
2. *a vessel being overtaken.*
3. *a sailing pilot vessel* on her station on pilotage duty. (This vessel also shows a flare every 10 minutes.)
4. *a steam trawler* or dredge net vessel, seen from a position more than 2 points abaft her beam.
5. *a sailing vessel trawling* or dredging. (This vessel also shows a flare on the approach of another vessel.)
6. *an open fishing boat,* steam or sail, with outlying gear extending not more than 150 feet.
7. *an open fishing boat,* steam or sail, with outlying gear extending more than 150 feet. (This vessel also shows a second white light on the approach of another vessel.)
8. *a fishing vessel under* 150 *feet in length* with gear fast to a rock.
9. *a fishing vessel under* 150 *feet in length* at anchor with gear attached. (This vessel also shows a second white light on the approach of another vessel.)

10. *a vessel under* 150 *feet in length* at anchor.
11. *a light vessel unable to show her usual light* on her station.
12. *a rowing boat.*

Two White Lights without Bow Lights may indicate :

1. *a steamship*, the side lights of which are out of visibility range.
2. *a vessel towing*, the side lights of which are out of visibility range.
3. *a steam vessel* trawling, seen from a position where she is head on or nearly head on.
4. *a fishing vessel* over 150 feet in length with gear fast to a rock.
5. *a fishing vessel* with gear extending more than 150 feet.
6. *a fishing vessel* with a drift net.
7. *a fishing vessel* line fishing.
8. *a fishing vessel* over 150 feet in length at anchor.
9. *a fishing vessel* over 150 feet in length at anchor with gear attached. (This vessel also shows a third white light on the approach of another vessel.)
10. *a fishing vessel* under 150 feet in length with gear attached.
11. *a vessel at anchor*, over 150 feet in length.

Two Vertical White Lights with Side Lights may indicate :

1. *a vessel towing.*
2. *a steamship* with additional steaming light, approaching bows on.

Three White Lights without Side Lights may indicate :

1. *a vessel towing* more than one vessel, the length of tow exceeding 600 feet, the side lights of which are out of visibility range.
2. *a fishing vessel* over 150 feet in length at anchor with gear attached.
3. *a British seine net vessel*, when they are seen in the form of a triangle.
4. *an examination service vessel* indicating that entrance to the port is permitted.

Two Vertical Red Lights may indicate :

1. *a vessel not under command*, with or without bow lights.
2. *a vessel aground in a fairway*. (This vessel also shows anchor lights.)
3. *a light vessel off her station*, seen from a position ahead or astern of her.

Three Vertical Red Lights may indicate :

1. *a vessel not under command* making way through the water, seen from a position on her port side.
2. *an examination service vessel*, indicating that entrance to the port is prohibited.

Not under Control Lights. The following types of vessels are *not* required to show 'not under control' signals by day or by night

if they lose command or go aground in or near a fairway. This is because they already carry special lights indicating the fact.

1. Vessels employed repairing or laying telegraph cables.
2. Small steam vessels under 40 tons.
3. Small sailing vessels under 20 tons.
4. Rowing boats.
5. All fishing vessels: trawlers, line-fishers, etc.

NAVIGATION LIGHTS

Arcs of Visibility. When a ship is built, the arcs of visibility are tested and made to comply with the *Instructions as to the Survey of Lights and Sound Signals* (Board of Trade).

If, for any reason, the navigating officer wishes to check the arcs, he can do so when the ship is in dock or alongside a jetty, where it is possible to mark and measure distances on shore.

The following points should be noted, but no alteration should be made to the lights without reference to the dockyard authorities.

1. An observer ahead of the ship should be able to see the full rays of both bow lights, simultaneously, at the following distances from the centre of the line joining the bow lights:

(*a*) 250 yards, when the lights are more than 40 feet apart.
(*b*) 200 yards, when the lights are more than 20 feet and less than 40 feet apart.
(*c*) 150 yards, when the lights are less than 20 feet apart.

When the observer is closer than these distances, it should not be possible to see both lights together.

2. Lights *must* show an unbroken light to two points abaft the beam.

3. Bow and steaming lights should fade out when the observer is three points abaft the beam, at a distance of 200 yards from the light. The overtaking light should fade out at the same distance, when the observer is one point abaft the beam.

Navigation Lights Carried by H.M. Ships

1. *At Sea.* Navigation lights and 'not under control' lights should always be tested before sunset.

At sunset, when navigation lights are switched on, they should be inspected to see that they are burning brightly. At the same time, oil navigation lights should be lit and placed in the vicinity of their respective brackets, in such a position that they cannot be seen from outboard the ship.

2. *In Harbour.* Power-driven boats of less than 40 tons are to carry one combined port and starboard bow lantern and one masthead lantern.

When there is no suitable position for the combined lantern, separate bow lanterns may be carried,

Ships' boats when under oars and away from their ships after dark, show a white light on the foremost awning stanchion.

Special Lights Carried by Flagships

1. *In Harbour* the presence of a *flag officer* in command is shown by lights carried in addition to the three stay lights.

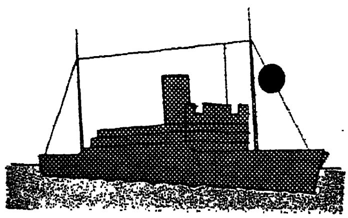
An Admiral: three stern lights and one top light.
A Vice-Admiral: two stern lights and one top light.
A Rear-Admiral or Commodore: one stern light and one top light.

Admirals' stern lights are carried aft, disposed horizontally over the largest convenient spread. They should be at the same level.

The top light is carried in the after part of the main top, and shows a white light over an arc of the horizon of 16 points; that is, from right astern to the beam on each side.

2. *At Sea.* Flagships carry only the top lights.

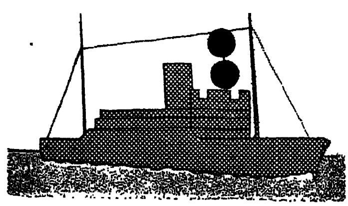
DAY SIGNALS AS SEEN FROM THE BRIDGE



A Vessel at Anchor

Carries forward, where it can best be seen, one black ball two feet in diameter.

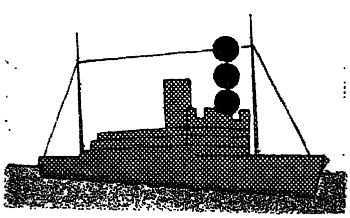
(Article 11.)



A Vessel not Under Control

Carries, where they can best be seen, two black balls each two feet in diameter, in a vertical line, not less than six feet apart.

(Article 4.)

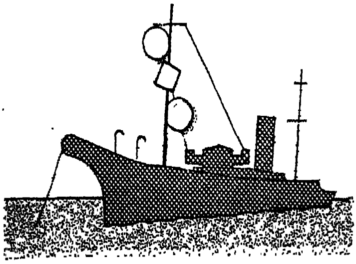


A Vessel Aground in a Fairway

Carries, where they can best be seen, three black balls each two feet in diameter, in a vertical line, not less than six feet apart.

(Article 11.)

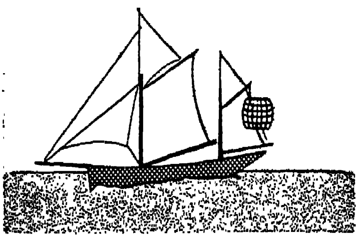
DAY SIGNALS AS SEEN FROM THE BRIDGE—*continued*



A Vessel Employed Repairing or Laying Telegraph Cables

Carries, where they can best be seen, two red balls in a vertical line, not less than twelve feet apart, with a white shape between them.

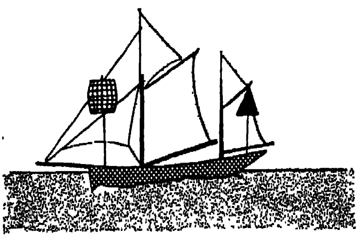
(Article 4.)



A Fishing Vessel

Indicates that she is fishing by hoisting a basket where it can best be seen. If at anchor with fishing gear out she hoists a basket on the side on which approaching vessels should pass.

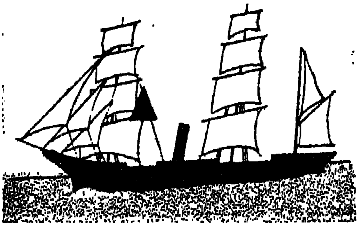
(Article 9.)



A Seine Net Vessel

Hoists a basket forward, and a cone at the yardarm in the direction of the net. On being approached by other vessels she sounds ▬ ▬ ▬ ▪ on a whistle. Seine nets may cover an area of one square mile.

(Article 9.)



A Vessel Proceeding under Sail and Steam

Hoists one black cone forward.

(Article 14.)

STEERING AND SAILING RULES

PRELIMINARY—RISK OF COLLISION

Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

TWO SAILING SHIPS MEETING

Article 17. When two sailing vessels are approaching one another so as to involve risk of collision, *one of them shall keep out of the way* of the other as follows, viz.:

(*a*) A vessel which is *running free* shall keep out of the way of a vessel which is close-hauled.

(*b*) A vessel which is *close-hauled on the port tack* shall keep out of the way of a vessel which is close-hauled on the *starboard tack*.

(*c*) When both are running free, with the wind on different sides, the vessel which has the *wind on the port side* shall keep out of the way of the other.

(*d*) When both are running free, with the wind on the same side, the *vessel which is to windward* shall keep out of the way of the vessel which is to leeward.

(*e*) A vessel which has the *wind aft* shall keep out of the way of the other vessel.

Article 18. When two steam-vessels are meeting end on, or nearly end on, so as to involve risk of collision, *each shall alter her course to starboard*, so that each may pass on the port side of the other.

This Article only applies to cases where vessels are meeting end on, or nearly end on, in such a manner as to involve risk of collision, and does not apply to two vessels which must, if both keep on their respective courses, pass clear of each other.

The only cases to which it does apply are, when each of two vessels is end on, or nearly end on, to the other; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own; and, by night, to cases in which each vessel is in such a position as to see both the side-lights of the other.

It does not apply, by day, to cases in which a vessel sees another ahead crossing her own course; or, by night, to cases where the red light of one vessel is opposed to the red light of the other, or where the green light of one vessel is opposed to the green light of the other, or where a red light without a green light, or a green light without a red light, is seen ahead, or where both green and red lights are seen anywhere but ahead.

TWO STEAMSHIPS CROSSING

Article 19. When two steam-vessels are crossing, so as to involve risk of collision, the vessel which has the other *on her own starboard side* shall keep out of the way of the other.

STEAMSHIP TO KEEP OUT OF THE WAY OF SAILING SHIP

Article 20. When a steam-vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, the *steam-vessel* shall keep out of the way of the sailing vessel.

VESSEL NOT GIVING WAY TO KEEP COURSE AND SPEED

Article 21. Where by any of these Rules one of two vessels is to keep out of the way, the other *shall keep her course and speed.*

NOTE. When, in consequence of thick weather or other causes, such vessel finds herself so close that collision cannot be avoided by the action of the giving-way vessel alone, she also shall *take such action as will best aid to avert collision.* (See Articles 27 and 29.)

AVOIDING CROSSING AHEAD

Article 22. Every vessel which is directed by these Rules to keep out of the way of another vessel shall, if the circumstances of the case admit, *avoid crossing ahead of the other.*

STEAMSHIP GIVING WAY TO SLACKEN SPEED

Article 23. Every steam-vessel which is directed by these Rules to keep out of the way of another vessel shall, on approaching her, if necessary, *slacken her speed, or stop, or reverse.*

SHIPS OVERTAKING OTHERS

Article 24. Notwithstanding anything contained in these Rules, every vessel overtaking any other, *shall keep out of the way of the overtaken vessel.*

Every vessel coming up with another vessel from any direction more than 2 points abaft her beam, *i.e.*, in such a position, with reference to the vessel which she is overtaking that at night she would be unable to see either of that vessel's side-lights, shall be deemed to be an overtaking vessel ; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these Rules, or relieve her of the duty of keeping clear of the overtaken vessel until she is *finally past and clear.*

As by day the overtaking vessel cannot always know with certainty whether she is forward of or abaft this direction from the other vessel, she should, *if in doubt,* assume that she is an overtaking vessel and *keep out of the way.*

IN NARROW CHANNELS

Article 25. In narrow channels every steam-vessel shall, when it is safe and practicable, *keep to that side* of the fairway or mid-channel which lies on the *starboard side of such vessel.*

KEEPING CLEAR OF FISHING BOATS

Article 26. Sailing vessels under way shall keep out of the way of *sailing vessels or boats fishing with nets, or lines, or trawls.* This Rule shall not give to any vessel or boat engaged in fishing the right of obstructing a fairway used by vessels other than fishing vessels or boats.

PROVISO AS TO DANGERS OF NAVIGATION, ETC.

Article 27. In obeying and construing these Rules, due regard shall be had to all dangers of navigation and collision, and to any *special circumstances* which may render a departure from the above Rules necessary in order to avoid immediate danger.

SOUND SIGNALS FOR VESSELS IN SIGHT OF ONE ANOTHER

Article 28. The words "*short blast*" used in this Article shall mean a blast of about *one second's duration.*

When vessels are in sight of one another, a steam-vessel under way, in taking any course authorised or required by these Rules, shall indicate that course by the following signals on her whistle or siren, viz.:

One short blast to mean, "I am directing my course to starboard."
Two short blasts to mean, "I am directing my course to port."
Three short blasts to mean, "My engines are going full speed astern."

NO VESSEL UNDER ANY CIRCUMSTANCES TO NEGLECT PROPER PRECAUTIONS

Article 29. Nothing in these Rules shall exonerate any vessel, or the owner, or master, or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper lookout, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

RESERVATION OF RULES FOR HARBOURS AND INLAND NAVIGATION

Article 30. Nothing in these Rules shall interfere with the operation of a special rule, duly made by local authority, relative to the navigation of any harbour, river, or inland waters.

DISTRESS SIGNALS

Article 31. When a vessel is in distress and requires assistance from other vessels or from the shore, the following shall be the

signals to be used or displayed by her, either together or separately, viz. :

In the Daytime :

1. A gun or other explosive signal fired at intervals of about a minute.
2. The International Code signal of distress. (International *NC*.)
3. The distance signal, consisting of a square flag, having either above or below it a ball or anything resembling a ball.
4. A continuous sounding with any fog-signal apparatus.
5. The international distress signal made by radiotelegraphy or radiotelephony, or by any other distance signalling method.

At Night :

1. A gun or other explosive signal fired at intervals of about a minute.
2. Flames on the vessel (as from a burning tar-barrel, oil-barrel, etc.).
3. Rockets or shells, throwing stars of any colour or description, fired one at a time at short intervals.
4. A continuous sounding with any fog-signal apparatus.
5. The international distress signal made by radiotelegraphy or radiotelephony, or by any other distant signalling method.

The use of any of the above signals, except for the purpose of indicating that a vessel is in distress, and the use of any signals which may be confused with any of the above signals, is prohibited.

SUMMARY OF ARTICLES 17–31

Article	17	Rules for avoiding collisions	between sailing vessels.
,,	18, 19	,, ,, ,, ,,	between steamships.
,,	20	,, ,, ,, ,,	between steamships and sailing vessels.
,,	21, 22, 23, 24	,, ,, ,, ,,	between all ships and vessels.
,,	25	,, ,, ,, ,,	in narrow channels.
,,	26	,, ,, ,, ,,	between sailing vessels and fishing craft.
,,	27	,, ,, ,, ,,	between all ships and vessels.
,,	28	Sound signals for vessels in sight of one another.	
,,	29	Rules for avoiding collisions	between all ships and vessels.
,,	30	Local harbour rules.	
,,	31	Distress signals.	

SUMMARY OF SIGNALS MADE DURING FOG, MIST, FALLING SNOW, OR HEAVY RAINSTORMS, WHETHER BY DAY OR NIGHT

Signal	*Made by*	*Interval*	*Signification*
One prolonged blast (▬)	Steam whistle or siren.	Every two minutes.	Steam vessel under way having way upon her.
Two prolonged blasts (▬ ▬)			Steam vessel under way, but stopped and having no way upon her.
One prolonged blast followed by two short blasts (▬ ▪ ▪).			(*a*) A steam vessel towing. (*b*) Vessel employed laying or picking up a submarine cable. (*c*) A steam vessel not under command or unable to manœuvre as required by the rules, but under way.
One blast	Foghorn	Every minute.	Sailing vessel under way on the starboard tack.
Two blasts in succession			Sailing vessel under way on the port tack.
Three blasts in succession			Sailing vessel under way with the wind abaft her beam.
One prolonged blast followed by two short blasts (▬ ▪ ▪).	Foghorn	Every two minutes.	Sailing vessel not under command, or sailing vessel towing another vessel.
One prolonged blast followed by three short blasts (▬ ▪ ▪ ▪).			Vessel being towed. If tow consists of more than one vessel, signal is made by the last vessel of the tow.
One short blast followed by one prolonged blast followed by one short blast (▪ ▬ ▪).	Any sound signal.	Every two minutes.	'The way is off my ship; you may feel your way past me.'
Bell rung rapidly for about five seconds.	Bell	Every minute.	Vessel less than 350 feet long at anchor.
Three separate and distinct strokes on the bell followed by the rapid ringing of the bell for 5 seconds followed by three separate and distinct strokes on the bell.	Bell	Every minute.	Vessel aground in or near a fairway.
Bell rung rapidly for about five seconds followed by sounding of gong.*	Bell and gong.*	Every minute.	Vessel over 350 feet long at anchor. (Bell forward, gong aft.*) * The use of a gong has not yet been ratified (1936).
One blast on whistle or siren followed by ringing of bell.	Bell and siren.	Every minute.	Steam fishing vessel, 20 tons gross tonnage or upwards, engaged in fishing.
One blast on foghorn followed by ringing of bell.	Foghorn and bell.	Every minute.	Sailing fishing vessel 20 tons gross tonnage or upwards, engaged in fishing.

(For signals by wreck-marking vessels and dredgers, see Chapter VII, and page 108.)

MISCELLANEOUS SIGNALS

The following signals may be made by flashing or sound signals by ships in sight of each other.

As sound signalling tends to cause confusion at sea these signals should be used with discretion. *In fog they should be reduced to a minimum.*

Signal	*Signification*
F (· · — ·)	I am disabled. Communicate with me.
K (— · —)	You should stop your vessel instantly.
L (· — · ·)	You should stop. I have something important to communicate.
O (— — —)	Man overboard.
P (· — — ·)	Your lights are out, or burning badly.
R (· — ·)	The way is off my ship. You may feel your way past me.
U (· · —)	You are standing into danger.
V (· · · —)	I require assistance.
W (· — —)	I require medical assistance.
Z (— — · ·)	Used by ships to address or call shore stations.

Searchlights. Any vessel approaching a British port and finding that searchlights are interfering with her safe navigation may make the following signal : — — · · — — —

Fishing Vessels. A fishing vessel wishing to communicate urgent information to H.M. ships at sea is to hoist a basket over the fishing burgee or pendant. (The pendant is usually very long and has the ship's name printed on it.)

Vessels Running Taut-Wire Gear fly flag 'T' International. They should not be approached inside 1,000 yards.

Vessels Running Speed Trials fly flag 'A' International, but International 'M F', which means 'pass me at slow speed', may also be used and should be obeyed.

British Pilot Signals. The following signals indicate that a ship requires a pilot.

By Day (Flag signal).

1. International 'G'.
2. International 'P T'.
3. Pilot jack at the foremast.

By Night

1. A pyrotechnical light, called a blue light, shown every 15 minutes.

2. A bright white light, flashed, or shown just above the bulwarks for about a minute, at short or frequent intervals.

3. International 'P T' by flashing.

In Fog. Isle of Wight and Plymouth district pilot vessels sound ▬ ▬▬ every two minutes.

CAUTION WITH REGARD TO SINGLE SHIPS APPROACHING SQUADRONS OR AIRCRAFT CARRIERS

(*Admiralty Notice to Mariners* issued at the beginning of each year)

1. The attention of shipowners and mariners is called to the danger to all concerned which is caused by single vessels approaching a squadron of warships so closely as to involve risk of collision, or attempting to pass ahead of, or through such squadron.

2. Mariners are warned that it would be in the interests of safety for single vessels to adopt early measures to avoid approaching a squadron under the above conditions which might involve risk of collision and to keep out of its way.

3. Attention is also drawn to the uncertainty of the movements of aircraft carriers which must necessarily turn into the wind when aircraft are taking off or landing.

4. In circumstances where a single vessel has not taken early measures to keep out of the way of a squadron or aircraft carrier, the *Regulations for Preventing Collisions at Sea* must be the guide.

Although this notice is issued annually, it must be borne in mind that *Admiralty Notices to Mariners* have only a limited circulation; also that it gives advice to mariners but is in no sense an international circulation.

It is never to be assumed that single vessels will adopt such measures. Officers of H.M. ships concerned should, therefore, keep a careful watch on single vessels and should be ready, if they do not give early indication of their intention to avoid the squadron, to take action in accordance with the collision regulations and good seamanship as may be required to avoid risk of collision.

NOTES ON RULE OF THE ROAD

Taking a Bearing of a Ship. The point normally to be observed, should be by day the compass platform, and by night the fore steaming light.

NOTE. When it is intended to pass under the stern of a ship, the point to be observed should be the stern.

Sighting a Light at Night. *When first sighting a light at night immediately take a bearing of it.* If the bearing:

1. remains constant, a collision must occur.
2. draws ahead, the other vessel will pass ahead of you.
3. draws aft, you will pass ahead of the other vessel.

Sighting a Light, the Bearing of which Remains Constant.

1. *If it is your duty to give way,*

never leave your alteration of course until the last moment.

Never make an alteration of course so small that your ship will only just clear the ship you are giving way to, but

always make an *early and pronounced* alteration of course, and

always make the appropriate sound signal as laid down in Article 28.

2. *If it is your duty to maintain a steady course and speed,*

always remember that the ship whose duty it is to give way may be keeping a bad lookout, in which event the note to Article 21 states: 'When, in consequence of bad weather or other causes, such vessel finds herself so close that collision cannot be avoided by the action of the giving-way vessel alone, she also shall *take such action as will best aid to avert collision.*'

Always remember that when in sight of another vessel and it is your duty to maintain a steady course, it may become necessary to alter course to avoid a navigational danger. When this occurs you *are to sound* the signals laid down in Article 28.

Always bear in mind that a ship whose duty it is to maintain her course and speed may have to alter course to avoid a navigational danger or, having rounded a danger, may alter to a new course for her destination, as for example, overtaking a ship in a buoyed channel.

Two Steam Vessels Meeting. When both side lights are sighted by night, or both masts in line by day, of a ship ahead or nearly ahead of you, it is laid down that both ships shall *alter course to starboard.*

Vessels Crossing. When giving way to another ship, avoid crossing ahead if possible. Pass astern, turn 180°, or stop engines.

When the bearing of a crossing vessel alters appreciably there can be no risk of collision; the crossing point must be ahead or astern.

Two Steam Vessels Meeting or Crossing in a Channel. If it is necessary for one vessel to wait, then the vessel to wait should be the one stemming the current or tidal stream.

Two Vessels Meeting at a Harbour Entrance. The general rule is that the incoming vessel should wait for the outgoing vessel to get clear of the entrance.

Two Sailing Vessels Close Hauled on the Same Tack. It is customary for the vessel to windward to give way.

Towing. A steam vessel towing *obeys* the rule of the road for a steam vessel, but does not show her main steaming light.

Trawlers. A steamship, and an unencumbered sailing vessel, must always *keep clear* of a trawler engaged in trawling.

Drift Net Vessels. It should be remembered that the nets of drift net vessels may extend for as much as 4 miles and that the vessel lies to leeward of her nets.

INTERNATIONAL COMMISSION FOR AIR NAVIGATION, 1919

(March 1935)

RULES AS TO LIGHTS AND SIGNALS

1. For the purpose of these Rules:

(*a*) An aircraft shall be deemed to be on the surface of the water when any part of the aircraft is in contact with the water.

(*b*) An aircraft, being in the air or on the surface of the water, shall be deemed to be under way when it is not moored to the ground or to any fixed object on the land or in the water.

(*c*) An aircraft under way in the air or on the surface of the water shall be deemed to be making way when it has a velocity relative to the air or water respectively.

(*d*) An aircraft shall be deemed not to be under control when it is unable to execute a manœuvre required in respect of it by the rules laid down in this Schedule or by the *Regulations for Preventing Collisions at Sea.*

(*e*) The expression "Visible", when used in relation to lights, means visible on a dark night with a clear atmosphere.

(*f*) The expression "plane of symmetry", in relation to an aircraft means the plane of symmetry passing through the longitudinal axis of the aircraft.

2. (i) The rules as to lights in this Section shall be complied with by aircraft in all weathers during the period from sunset to sunrise.

(ii) Throughout the period during which the rules aforesaid are to be complied with, no other lights shall be displayed which may be mistaken for the lights required to be displayed by those rules.

(iii) The lights required to be displayed by the said rules shall not be dazzling.

3. (i) Every flying machine in the air or on a land aerodrome shall display the following lights, that is to say:

(*a*) on the right side, a green light, fixed so as to show an unbroken light visible at a distance of at least 5 miles in a dihedral angle of 110° formed by two vertical planes, one of which is parallel to the plane of symmetry and directed dead ahead, and the other is directed to the right;

(*b*) on the left side, a red light, fixed so as to show an unbroken light visible at a distance of at least 5 miles in a dihedral angle of 110° formed by two vertical planes, one of which is parallel to the plane of symmetry and directed dead ahead, and the other is directed to the left;

(*c*) at the rear, a white light, fixed so as to show astern an unbroken light, visible at a distance of at least 3 miles in a dihedral angle of 140° formed by two vertical planes bisected by the plane of symmetry.

(ii) In a case where, in order to comply with the foregoing provisions of this paragraph, a single light has to be replaced by several lights, the field of visibility of each of those lights should be so limited that only one can be seen at a time.

(iii) In the case of a flying machine with a maximum span of less than 65 feet, the lights required by this paragraph may be combined in one or more lamps, placed centrally, provided that the requirements of this paragraph as to colour and visibility are complied with.

4. Every flying machine under way on the surface of the water shall display lights in accordance with the following provisions of this paragraph :

(*a*) if it is under way and not being towed, it shall display the lights required by paragraph 3 of this Schedule, and in addition, forward, a white light fixed so as to show forward an unbroken light visible at a distance of at least 3 miles in a dihedral angle of 220° formed by two vertical planes and bisected by the plane of symmetry ;

(*b*) if it is being towed, it shall display the lights required by paragraph 3 of this Schedule ;

(*c*) if it is not under control, it shall display two red lights placed where they can best be seen, one vertically over the other, not less than 3 feet apart, and both being visible, so far as practicable, all round the horizon at a distance of at least 2 miles, and it shall also display:

(i) if making way, the lights required by paragraph 3 of this Schedule; or

(ii) if not making way, the light required by sub-paragraph (i) (*c*) of paragraph 3 of this Schedule.

5. Every flying machine at anchor or moored on the surface of the water, shall display lights in accordance with the following provisions of this paragraph:

(*a*) in every case, it shall display forward centrally where it can best be seen, a white light, visible all round the horizon at a distance of at least 1 mile;

(*b*) in a case where the length of the flying machine is 150 feet or upwards, it shall display, in addition to any other light

required by this paragraph, a white light at or near its stern at lower height than the lights mentioned in sub-paragraph (*a*) of this paragraph, and visible all round the horizon at a distance of at least 1 mile;

(*c*) in a case where the maximum span of the flying machine is 150 feet or upwards, it shall display, in addition to any other light required by this paragraph, a white light on each side placed in such a manner as to demarcate the maximum lateral dimension of the flying machine, and visible, so far as practicable, all round the horizon, at a distance of at least 1 mile.

6. When an aircraft is threatened by grave and imminent danger and requires immediate assistance, the following shall be the signals of distress to be used or displayed, either together or separately:

(*a*) The international signal *S O S*, by means of visual or wireless signals;

(*b*) The international distress call *Mayday* (corresponding to the French pronunciation of the expression *m'aidez*) by means of radiotelephony;

(*c*) The international code flag signal of distress, indicated by *N C*;

(*d*) The distant signal, consisting of a square flag having either above or below it a ball, or anything resembling a ball;

(*e*) A continuous sounding with any sound apparatus;

(*f*) A signal, consisting of a succession of white pyrotechnical lights fired at short intervals;

(*g*) A white flare ejecting a white light about every 3 seconds.

7. (i) Where an aircraft has a message to send stating that it is in difficulties and about to land compulsorily but does not require immediate assistance, it shall preface the call with several repetitions of the urgency signal *PAN*.

(ii) Where the signal *PAN* is received from an aircraft without any message following, it shall signify that the aircraft has been compelled to land and is unable to transmit its intended message owing to the rapidity of the landing, but does not require immediate assistance.

(iii) Where the signal *PAN* is sent by radiotelegraphy, the three letters shall be well separated so that the signals *AN* are not transformed into one signal *P*.

(iv) Where the signal *PAN* is sent by radiotelephony, it should be pronounced like the French word *panne*.

8. When an aircraft has a very urgent message to send concerning the safety of the aircraft, or of any person on board, or of any ship or aircraft or person within range of assistance, the urgency of the message shall be indicated by an urgency signal as follows:

(*a*) In visual signalling, by prefacing the call with a succession of green pyrotechnical lights or a succession of green flashes made with the daylight signalling apparatus.

(*b*) In radiotelegraphy, by prefacing the call with several repetitions of the group *XXX*, the letters of each group and the successive groups being clearly separated from each other.

9. Where an aircraft has a message to send concerning the safety of navigation or containing important information relative to meteorological warning messages, it shall first transmit the safety signal as follows :

(*a*) In radiotelegraphy, the safety signal consists of three repetitions of the group *TTT*, with the letters of each group and the successive groups well separated. This signal should be followed by the word *DE* and by the call sign of the aircraft three times repeated.

(*b*) In radiotelephony, the safety signal consists of the French word *securité* (corresponding to the English pronunciation of the syllables *say-cure-e-tay*), repeated three times. This signal shall be followed by the call sign of the aircraft three times repeated.

10. To warn an aircraft that it is in the vicinity of a prohibited area and should change its course, the following signals shall be used :

(*a*) By day : three projectiles discharged at intervals of 10 seconds, each showing, on bursting, white smoke, the location of the burst indicating the direction the aircraft should follow.

(*b*) By night : three projectiles discharged at intervals of 10 seconds, each showing, on bursting, white lights or stars, the location of the burst indicating the direction the aircraft should follow.

11. To require an aircraft to land, the following signals should be used :

(*a*) By day : three projectiles discharged at intervals of 10 seconds, each showing on bursting, black or yellow smoke.

(*b*) By night : three projectiles discharged at intervals of 10 seconds, each showing on bursting, green lights or stars.

In addition, when necessary to prevent the landing of aircraft other than the one ordered, a searchlight, which shall be flashed intermittently, shall be directed towards the aircraft whose landing is required.

12. In fog, mist, falling snow or heavy rainstorm, whether by day or night, an aircraft on the water shall make the following sound signals :

(*a*) If not anchored or moored, a sound at intervals of not more than 2 minutes, consisting of two blasts of about 5 seconds duration with an interval of about 1 second between them.

(*b*) If at anchor or moored, the rapid ringing of an efficient bell or gong for about 5 seconds at intervals of not more than 1 minute.

13. Every aircraft manœuvring under its own power on the water shall conform to the *Regulations for Preventing Collisions at Sea*, and for the purposes of these regulations shall be deemed to be a steam vessel, but shall only carry the lights specified in the preceding rules, and not those specified for steam vessels in the *Regulations for Preventing Collisions at Sea*, and shall not use, except as specified in paragraphs 6 and 12 above, or be deemed to hear the sound signals specified in the above-mentioned Regulations.

14. In conforming with the rules laid down in this Schedule:

(*a*) due regard shall be had to all dangers of navigation and collision and to any special circumstances which may render a departure from those rules necessary in order to avoid immediate danger; and

(*b*) in particular it shall be borne in mind that steam vessels in narrow channels are not able to manœuvre so as to avoid collision with aircraft.

SUMMARY OF AIRCRAFT LIGHTS, SIGNALS, ETC.

Lights of Aircraft at Anchor. (*Notices to Mariners*, Edition No. 1 of each year.)

1. Forward, centrally, where best seen, a white light.
2. If the aircraft is 150 feet or more in length, an additional white light is carried at or near the stern, lower than the forward lights.
3. If the span is 150 feet or more, an additional white light is carried on each side, making the maximum lateral dimension.

All lights visible all round the horizon for at least 1 mile.

Aircraft Urgency Signals between Merchant Ships and British Aircraft in Distress.

1. An aircraft wishing to communicate, flies low round the ship, and fires green Verey lights to attract attention. It then signals by V/S; an aircraft, not fitted with V/S, flies low round the ship, fires green Verey lights, and then proceeds in the direction of distress or alights to pass the message.
2. *X X X* made three times by W/T before the message.

Aircraft Distress Signals.

1. *S O S* by V/S or W/T.
2. *Mayday* by R/T.
3. *N C* in the International Code, by any method.
4. Hoisting a square flag, with a ball above or below it.
5. Continuous sounding of any sound apparatus.
6. Firing white pyrotechnical lights at short intervals.
7. Showing a white flare, ejecting a white light every 3 seconds.

NOTE. *S O S* is sent three times and is followed by *D E*, the call sign of the aircraft, the position, the cause of distress, and the form of assistance required.

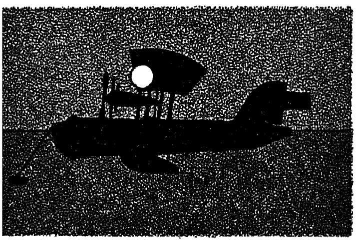
Aircraft Safety Signals. The following signals are only to be used when aircraft wish to pass a message concerning navigational safety, or important meteorological warnings.

1. By W/T : *T T T*, made three times and followed by *D E*.
2. *Securité*, made three times by R/T.

Aircraft Sighted—Notation in Log. To assist in searching for aircraft in distress, the following particulars are to be noted in the logs of H.M. ships and Royal Fleet Auxiliaries.

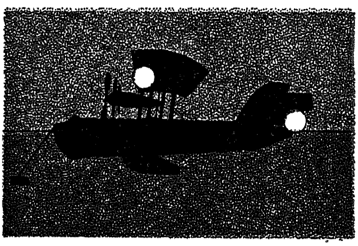
1. Details of aircraft sighted in flight at sea.
2. Time of observation.
3. Identification marks, if possible.
4. Other particulars that might assist in identification.

LIGHTS OF AIRCRAFT AT ANCHOR AS SEEN FROM THE BRIDGE



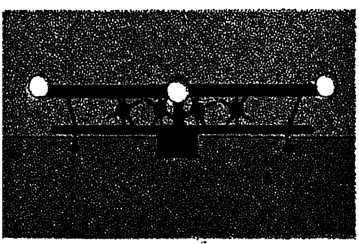
Aircraft under 150 feet long

Carry one all-round white light forward centrally. Visible 1 mile.



Aircraft over 150 feet long

Carry in addition to the light shown in figure 1, an all-round white light at or near the stern, and lower than the forward light. Visible 1 mile.



Aircraft with a Wing Span Exceeding 150 feet

Carry, in addition to the requisite lights shown in figures 1 and 2, two all-round white lights, one on each side, to mark the lateral dimensions.

CHAPTER VII

NAVIGATION IN PILOTAGE WATERS

Navigation in pilotage waters will be considered under the following headings :

Coasting, that is when the ship has to be navigated from headland to headland, generally in sight of, or sufficiently often in sight of land to make fixing by heavenly bodies unnecessary.

Channel Navigation, that is when the ship has to be navigated in narrow channels with dangers on both sides, and in rivers and harbours, and their approaches.

Canal Navigation
Navigation in Coral Regions } described at the end of the chapter.

PREPARATORY WORK

Always be Thinking Ahead

There are many points that the navigator should consider before the ship proceeds to sea or reaches the coast on an ocean passage. He should, for instance :

1. consult the *Sailing Directions*, *Light Lists*, tidal publications and local orders.

2. consider the possibility of meeting fog or low visibility when the ship is passing through channels or narrow waters and anticipate what action will then be required.

3. consider the probable ship's position at dusk and through the night.

NOTE. It is a good plan to work out the distance at which conspicuous lights should be visible from the height of eye of the bridge and to draw pencil circles round them at these distances. The time when lights should be sighted can then be seen from the chart without calculation, and if they are seen an approximate fix can be obtained by the methods described on page 67.

Possible dangers can be considered, and if the speed at which the ship will proceed is known, the courses that it is proposed to steer can be drawn on the charts and noted in the notebook, together with the time on each course, the bearings on which to alter course and the tidal stream or current expected. Notes on leading lines, conspicuous objects, times of sunrise, moonrise, etc. and the time of turning of the tidal stream, should also be included in the notebook.

THE RECORD

The continuous record of the ship's track, when in pilotage waters, will be invaluable for future reference when the same passage is made, particularly if the subsequent passage is made in thick weather.

AT SEA IN PILOTAGE WATERS

It is most important that the position of the ship shall always be known, and this entails thinking ahead and constant fixing.

NOTE. It is often difficult to identify objects on the shore; a charted church or chimney may actually be close to other churches and chimneys which are not shown on the chart. For this reason, WHEN FIXING, ALWAYS USE THREE OBJECTS so that any error of identity will become apparent.

COASTING

The general rule in coasting is to pass sufficiently close to the shore to enable all prominent marks, such as lighthouses, etc., to be seen, and to obtain frequent fixes.

To decide at what distance from dangers and coasts the ship should pass requires experience, but the course steered should, as far as possible, be such that, if fog or mist should obscure the marks, the ship could still be navigated with the certainty that she is not running into danger. For this reason avoid a course converging with the coast.

The following notes will serve as a rough guide when the track of a ship is laid off, but it should be borne in mind that the distances will have to be adjusted for the prevailing weather and tidal streams or currents likely to be experienced, and for the nature of the coast or dangers being approached and the probable opportunities for fixing the ship's position.

1. When the coast is fairly steep, to pass at a distance of 2 miles or over. At 2 miles objects can easily be recognised in normal weather.

2. When the coast is shelving:
   (*a*) deep draught ships drawing over 20 feet should pass outside the 10 fathom line.
   (*b*) medium draught ships drawing 10 to 20 feet should pass outside the 5 fathom line.
   (*c*) light draught ships drawing under 10 feet should pass outside the 3 fathom line.

3. When there are dangers near the coast the position of which is not certain, pass at least 1 mile from them if there is sea-room and sufficient objects are available to ensure frequent fixing.

In tidal waters and in thick weather increase this distance.

4. Buoys and light-vessels should be passed at a distance of 5 cables if there is sea-room.

5. Where there are unmarked dangers out of sight of land, pass them at a distance of 5 to 10 miles depending on the time interval since the last fix and the tidal stream or current likely to be experienced.

During dark hours these distances should be increased.

When the track will lead the ship into comparatively shallow water, such as the estuaries of rivers or the approaches to harbours, it is essential to consider the height of the tide in relation to the draught of the ship. An ample margin of depth should always be allowed.

It is a good plan to mark dangers on the chart in red pencil, or to shade inside a depth line greater than the draught: for example, if a ship draws 20 feet, shade in the area inside the 5 fathom line which will serve as a dead line. The margin of safety to be allowed cannot be laid down, but must depend upon circumstances.

In order that the ship may proceed with safety when in the vicinity of land or dangers, the track should, as far as possible, be so arranged that it coincides with a transit or a line of bearing. Any deviation of the ship from her track will thus become apparent from one bearing of the object ahead or astern and, in addition, if the ship is known to be following her intended track, a position line from a bearing of an object abeam will immediately fix her position.

Transits. When possible, arrange the track so that two objects in transit may be seen ahead or astern; in other words, arrange that the ship may steam along the position line resulting from this transit. If the two objects are seen to remain in transit the ship is following the arranged track, whereas if they are seen to be not exactly in line with each other, it is obvious that the ship is to the right or left of the pre-arranged track.

The value of a line of transit is proportional to the ratio of the distance between the objects in transit to the distance between the ship and the nearer object. The larger this ratio the better the transit. If possible the ratio should not be less than one-third.

Marks are said to be open when they are not exactly in transit. Thus in figure 51 a chimney and a lighthouse are in transit to an observer O, but to an observer at C the chimney is said to be open to the right of the lighthouse.

If the objects are observed to be open, then regain the line with a bold alteration of course.

Many harbour plans show two marks which, being kept in transit, lead the ship clear of dangers, or in the best channel. Such marks are called *leading marks*, and they are shown on a chart by a line drawn through them called a *leading line*. The line is generally shown as one straight line but sometimes as two parallel lines close together. The line is full, or double for a part of its length, and then becomes dotted or single. This signifies that it is

advisable to keep on it only as far as the full or double line extends, the dotted or single portion being drawn to guide the eye to the objects which are to be kept in transit. The names of the objects and their true bearings from seaward, when in transit, are generally written along the line drawn through them. Thus in figure 51 if OB were a charted leading line, this fact would have printed along it: chimney ø lighthouse 000°, or chimney in line with lighthouse 000°.

When the objects are in transit, a bearing of them should be taken and compared with that given on the chart. This ensures that the two objects seen in transit are the correct objects, and also checks the error of the compass.

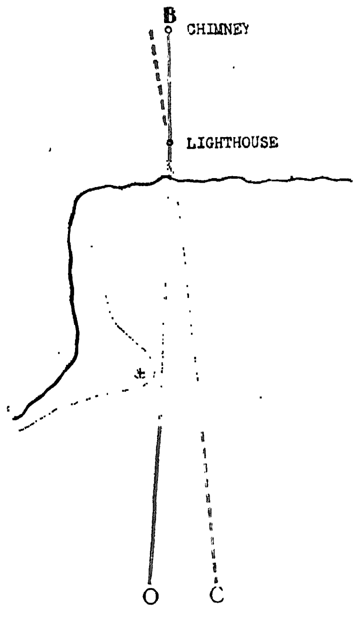


FIGURE 51.

Line of Bearing. If no transit marks are available, a line of bearing should be used. The track is drawn on the chart to pass through some well-defined object, either ahead or astern, preferably ahead of the ship, and the bearing of this line noted. Provided the bearing of the object remains at the bearing noted, the ship must be on her track, and if the bearing changes, the ship will have been set off the track, and the alteration of course necessary to regain the line of bearing can be found by:

1. setting the azimuth circle on the correct bearing; then, with the object ahead of the ship, if the object is to the left, the ship must be moved to the left by an alteration of course to port or *vice versa*. If the object is astern this procedure must be reversed.

2. referring to the note book, where the prudent navigator will have stated how the bearing will change should the ship be set to port or starboard of the line; for example:

Eddystone lighthouse 300°.
Bearing *more*, ship is to *port* of the line.
Bearing *less*, ship is to *starboard* of the line.

There can thus be no possible doubt upon the way to alter course to regain the line.

It is often possible when steaming on a line of bearing to observe some uncharted object, such as a telegraph pole or gap in the trees, which is in transit with the object through which the line of bearing has been drawn. This transit is of great assistance in keeping the ship on the line.

When laying off a line of bearing, choose an object which is not too far away. The closer the object is to the observer the easier it is to detect by the change of bearing when the ship is being set off the line. For example, if the object is one mile distant, the bearing will alter one degree if the ship is set about 35 yards off the line, whereas if it is 10 miles distant the ship will be set about two cables off the line before the bearing changes one degree.

Clearing Marks. These are two marks shown on the chart, the straight line through which, called a *clearing line*, runs clear of certain dangers. When navigating near a danger, take care not to go inside the transit line of the clearing marks. So long as the ship is outside this line, that is so long as the marks are kept open, she is safe from the danger. In figure 51, the clearing marks for the dangerous rocks are given by the transit OB.

Clearing Bearings. When no clearing marks are available, draw a line of bearing on the chart through some conspicuous point so as to pass at a certain distance from a danger. This line of bearing is called a clearing bearing and if the ship steams along the line she is safe from the danger.

By watching the bearing of the chosen object, when in the vicinity of the danger, it can be seen at once if the ship is on the safe side of the line.

The Vertical Danger Angle. A vertical sextant angle can be used with advantage to ensure the safety of the ship in the vicinity of dangers.

If the danger to be guarded against is close to high land or a lighthouse, proceed as shown in the following example:

It is required to pass 5 cables clear of a rock which is distant 3 cables from a lighthouse, shown in figure 52. The height of the lighthouse is 150 feet above mean high water springs.

With centre the lighthouse and radius 8 cables, describe a circle. Find the actual height of the lighthouse above sea level by allowing for the difference between the height of the tide and the height of mean high water springs.

Lecky's Danger Angle and Off-Shore Distance Tables, or the masthead angle tables in *Inman's Tables*, will give the angle subtended between the top of the lighthouse and the sea level from any point on the arc of the circle.

Place this angle on a sextant, and so long as the reflected image of the top of the lighthouse appears below the water level, the ship is outside the circle and in safety.

If the height of the tide is not allowed for, and the height of the light as printed on the chart is used, the ship will actually be farther

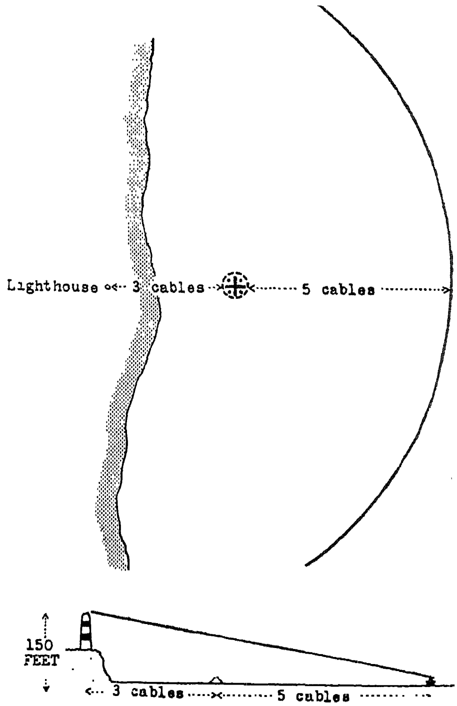


FIGURE 52.

from the light than estimated, except in the unlikely event of the sea level's being above mean high water springs.

Rangefinders. A rangefinder will give a position line, as described in Chapter IV, which can be used in a similar way to the vertical danger angle. In the above example, shown in figure 52, if the range of the lighthouse always exceeds 1,600 yards, the ship will pass not less than 5 cables from the rock. A rangefinder is most useful at night when one light may be the only visible object to assist the ship in avoiding a danger.

NOTE. When a rangefinder is to be used for navigation, the navigating officer should ensure that it is checked before leaving harbour and at every subsequent opportunity. A rangefinder should not be used when there are objects available for fixing the ship's position by cross bearings.

The Horizontal Danger Angle. The horizontal angle between two objects on shore may be used in a similar way. The objects should be chosen so as to lie approximately at the same distance on each side of the danger to be cleared. A mark should be made on the chart at a distance outside the danger at which it is considered safe to pass, and lines drawn from the objects to this mark. The angle thus formed is measured, and if the angle subtended by the objects is less than that measured, the ship is outside the danger and in safety.

In figure 53, the horizontal sextant angle between the lighthouse and the flagstaff is observed to be 78°. If the horizontal angle between these two objects is less than 78°, the ship is outside the circle passing through the three points, and must pass clear of the rock.

When the angle subtended by the objects is less than the angle

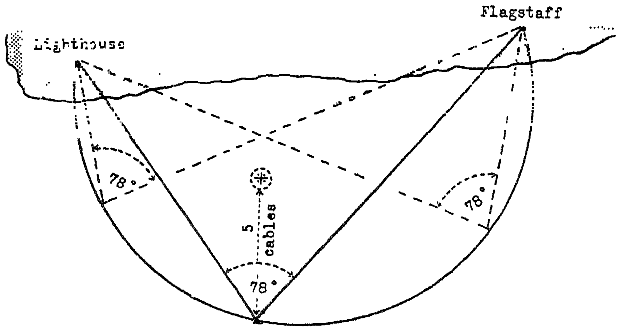


FIGURE 53.

set on the sextant, the flagstaff will appear to the left of the lighthouse.

Fixing the Ship when Coasting

1. *Fix frequently* when possible. Note the bearings and *time* of each fix in the notebook.

2. *Always* choose objects close to the ship in preference to objects far away. It is preferable to fix at equal intervals of time and so get a constant check on the speed made good.

3. *Always use the largest-scale chart.*

4. Having fixed the ship's position on the chart *always* write the time against it and project the course made good for a further distance equivalent to a run of 10 minutes or so.

The present position of the ship should always be on the chart.

Write the course on the middle of the line on the chart which represents it.

5. *Keep a careful and continuous reckoning* on the chart and in the notebook, and *ensure* that this is done without intermission throughout the time the ship is at sea.

6. Do not have two charts on the chart table at the same time because the scales may become mixed.

7. When passing between islands, if practicable, always use objects on the same shore. For example, when in the Solent do not include in the same fix objects on the Isle of Wight and on the mainland, but fix either by objects all of which are on the Isle of Wight or all of which are on the mainland.

8. In taking a bearing of a tangent of an island or point of land, there may be an error if the shore is shelving and the tide is above chart datum. What may appear as a long point at low water disappears with the rise of the tide. This error is emphasized where there is a great tidal range.

9. Many fixes may be unnecessary, but fog or rain squalls may reduce the visibility without warning.

When Not to Fix. On occasions when there are only mountain summits, or distant or inconspicuous marks visible, a fix may give a position widely different from the ship's estimated position.

If there is no reason to mistrust the estimated position, a fix in these circumstances should be treated with caution.

PILOTAGE IN NARROW WATERS

When rounding points of land or shoals, allow plenty of room; cutting corners is dangerous.

When navigating in narrow waters, where there is likely to be much traffic, always keep on that side of the channel which is on the starboard hand.

If possible, always steer on marks that are ahead or astern.

Turning on to a Mark. Always allow for the distance to new course as explained on page 146, and do not wait until the marks are on before putting the wheel over. When there is a cross tidal stream, make the necessary allowance immediately on turning to the mark and caution the helmsman to steer by the compass and not by the land. By carefully watching the mark it will soon be seen whether too much or too little allowance has been made, and the error can be corrected.

Buoys and Light-Vessels

Do not trust implicitly to buoys because they are only intended as an aid to navigation.

Do not fix by buoys when other objects are visible *close* to the ship.

Remember that the buoys marking a shoal are frequently changed as the shoal extends and there may not be information of the alterations. Thus a fix by shore objects will not necessarily give you a correct position *relative to a shoal*, because the latter may have extended and the new position may be shown by the buoys.

Always compare the name, colour, topmark, etc. of each buoy with that shown on the chart, to avoid the possibility of mistaking one buoy for another.

When a buoy is passed, it is easy to see at a glance in what direction the tidal stream is running. Similarly the way in which a light-vessel is swung will tell the direction of the tidal stream if the wind is not so strong that the vessel is swung across the stream.

A ship passing near any light-vessel that has clear water on *both* sides of her should pass under her stern and not across her bows, because any under-estimation of the strength of the stream may cause a collision if she crosses the bows.

Low-Lying Land. When the land is too indistinct for the ship's position to be fixed by bearings of shore objects, fix by bearings of beacons and light-vessels, if they are available, in preference to bearings of buoys.

In certain places where the shore is distant and low-lying, as for instance in the Thames estuary, buoys may be the only guide. Before arriving at such a locality, especially if the weather is likely to be thick, lay down all the courses necessary to steer on the chart, making due allowance for the tidal stream that should be running at the time. Note the various courses, the distance on each course, and the time it will take to steam from buoy to buoy, or beacon to beacon.

If after passing one buoy, the calculated time of arrival at a second buoy elapses and the expected buoy is not in sight, *proceed with the utmost caution.*

When Altering Course on the Changing Sectors of a Light. Always note the bearing when the light should change its colour and alter course on this compass bearing because it is almost impossible to decide exactly when a light changes from one colour to another.

NOTES ON COASTING

1. **Lights.** Never pass a light without checking its period and characteristics.

2. **Buoys and Seamarks.** Buoys and seamarks are moved occasionally by local authorities *before* the information has time to be embodied on the chart. Also movements reported by the authorities which *have* been embodied on the chart are sometimes delayed.

3. **Light-Buoys.** Do not rely on light-buoys when they are unsupported by other aids to navigation because they sometimes go out.

4. **Bays.** Remember that there is often an indraught into bays and bights.

5. **Calculating the Distance that an Object will Pass Abeam.** It is a help in coasting to be able to determine, with a simple mental calculation, the distance a ship will pass an object abeam on a certain course and how much the course must be changed in order to pass the object a desired distance away.

One mile subtends an angle of one degree at a distance of 60 miles.

Two and a half cables subtend an angle of one degree at a distance of 15 miles.

For example :

(*a*) A light is sighted right ahead at an estimated distance of 15′ and it is desired to pass 4′ from the light. What alteration of course is necessary ?

1 degree at a distance of 15′ is equivalent to $\frac{1}{4}$ mile. The alteration required is therefore 16 degrees.

Alter course to bring the light 16 degrees on the bow.

(*b*) A light is sighted 10 degrees on the bow at an estimated distance of 12′ and it is desired to pass 4′ from the light. What alteration of course is necessary ?

For 12′ the estimated departure per degree is $60/12 = \frac{1}{5}$ mile. To pass 4′ therefore, alter course out 10 degrees from the present course to bring the light $4 \times 5 = 20$ degrees on the bow.

NOTE. (i) Allowance must be made for any tidal stream or current.
(ii) When rounding a point which is very close to the ship and it is desired to keep at a constant distance from it during the turn, put the rudder over an amount corresponding to the tactical diameter required, a little before the point is on the beam, and subsequently continue to adjust the rudder angle so that the object remains abeam throughout the turn.

6. **Making a Poorly Charted Coast by Day.** When it is necessary to make a flat coast by day, running north and south, say, which is known to have few prominent objects, considerable time may be saved if a position 5 or 10 miles north or south of the required position is steered for. On sighting the coast, alter in the required direction until objects can be picked out and a fix obtained. An example of this principle is given on page 143.

7. **Using a Poorly Surveyed Chart.** When there are few lines of sounding on the chart, proceed with caution, following the lines of soundings on the chart where practicable.

8. **Compasses**

(*a*) Check the gyro and magnetic compasses on a transit after each alteration of course.

(*b*) Be prepared to rely on the magnetic compass. Even with two master gyro compasses a drop in the ship's voltage may cause an error in *both* master compasses.

(*c*) A good plan is to arrange the compasses as follows:
- (i) Steering repeater and starboard wing repeater on No. 1 master compass.
- (ii) Pelorus and port wing repeater on No. 2 master compass.

The officer of the watch and the navigating officer should *constantly* check the magnetic compass with the gyro repeater.

9. **Sighting Other Ships**

(*a*) When altering course in accordance with the rule of the road *always*:
- (i) alter course in plenty of time
- (ii) alter a sufficient amount to make your intention quite clear.
- (iii) do not resume the original course until all risk of collision is past.

(*b*) The following remarks are taken from *On the Bridge**:

"At sea, whether nearing danger or otherwise, there is no reason to assume that any vessel sighted, steering a similar course to ourselves, should—

(*a*) Be trying to go to our destination.

(*b*) Be navigated with more skill than our own craft.

"However, on certain well-defined routes it is sometimes possible to note whether the ship is in the fashion—or inshore or outside of it."

10. **Proceeding Along the Side of a Dredged Channel.** A ship has a tendency to sheer away from the bank, an effect which is accelerated by speed.

11. **Care of the Chart.** The surface of the chart can best be preserved and plotting will be much clearer if a soft pencil (B or BB) and a soft rubber are used. In wet weather it is a good plan to place a towel along the front of the chart table to lean on, and to remove your cap when working on the chart.

12. **Chart Table at Night.** When the chart is studied at night in a chart table not fitted with a dimming switch, it is an advantage to close one eye when the light is switched on and later, when in darkness again, to open the closed eye. The temporary blindness caused by the light will be lessened and vision much improved.

FOG AND THICK WEATHER

When it is seen that the ship is about to enter fog, *always note in the bridge notebook* the approximate bearing, distance and course of any ships in sight.

On Entering Fog always

1. **Reduce to a Moderate Speed.** Moderate speed in a fog is held by the courts to be "such a rate of speed as will enable a vessel,

* *On the Bridge*, by Captain J. A. G. Troup, R.N. (Rich and Cowan).

after discovering another vessel meeting her, to stop and reverse her engines in sufficient time to prevent any collision from taking place".

2. Close up lookouts. A good plan is to have two lookouts on the forecastle and two at the masthead, each with his own sector. Lookouts should be in direct telephonic communication with the bridge or be supplied with megaphones. Forecastle lookouts should be taught to point.

3. Close up the sounding party.

4. In the vicinity of land, have an anchor ready for letting go.

5. Order silence on deck

6. Close watertight doors in accordance with the ship's standing orders.

7. Start the prescribed fog signal.

8. Warn the engine-room.

9. Decide if it is necessary to light extra boilers.

10. Memorise the characteristics of air fog signals which may be heard.

11. Listen for submarine fog signals if there are any in the vicinity.

12. Listen for W/T fog signals and arrange to take W/T—D/F bearings. D/F bearings of ships in the vicinity may prove to be of the utmost value.

When hearing before the beam the fog signal of a vessel, the position of which is not certain, if circumstances permit you should stop engines and then navigate with caution. Note in the log the exact time at which the engines are stopped.

Remember that sound signals in fog tend to cause confusion and the sound signals in Article 28 of the *International Regulations for Preventing Collisions at Sea* are for vessels *in sight of one another.*

Visibility. If a range can be obtained on first sighting a ship or object, the visibility can be determined. If the visibility is known, a rough fix is obtained by combining that distance with the bearing of a known object.

The visibility of buoys can be found by noting the time when a buoy is passed and the time when it disappears. Visibility circles can then be drawn on the chart round succeeding buoys, and this will help to estimate when they should appear.

If there is better visibility from the upper deck or masthead than from the bridge, then the bearing of an object sighted from either of these positions will have to be relative to the fore-and-aft line as there will be no compass available, but the rough estimate of when the object is abeam from these positions will almost certainly improve the estimated position.

When fog is low lying, the smoke of ships in the vicinity may frequently be seen above the fog; hence the need for a lookout as high as possible.

When it is necessary, in low visibility, to make a lighthouse which is steep-to all round, it may not be possible to predict on which bow the lighthouse will appear. Turn *away* as soon as the lighthouse is sighted.

Siren Echo. If the echo of the siren can be heard, a rough distance from the cliffs can be estimated from the following formula:

$$\text{Number of feet from cliff} = \frac{\text{Number of seconds elapsed} \times 1{,}130}{2}$$

or roughly:

distance in cables=the number of seconds less one-tenth.

Fog Signals. Do not rely on hearing a fog signal from a light-vessel or lighthouse, because sound is capricious in a fog, and there are often large areas into which the sound does not penetrate. Also the ship may be near the inner edge of a fog that is approaching the land and has not been noticed from the fog-signal station, in which event the fog signal, which sometimes takes time to get ready, may not be working.

The sound signals on some buoys and unwatched light-vessels are operated by the motion of the sea and, since in foggy weather the sea is usually calm, they may not sound.

H.M. ships are not allowed to rely on the sounding machine as their only guide when approaching the land in a fog.

Little information can be obtained from one sounding, but if a continuous line of soundings is taken, they may afford an excellent guide to the position of the ship, as explained on page 79.

Running a Line of Soundings. This method of fixing the ship's position, described in Chapter IV, is most useful in thick weather.

Submarine Fog Signals. A submarine fog signal is a useful guide in a fog, because from it a line of bearing can be obtained if the ship is fitted with receiving gear.

Wireless Fog Signals. Wireless fog signals are of great assistance in a fog, especially if transmitted in conjunction with a submarine fog signal, which is often done in light-vessels. The bearing of the light-vessel is found by a direction-finding bearing of her W/T signal, or by the submarine fog signal. The distance of the light-vessel is found by timing the interval between the wireless and the submarine signals. If this interval in seconds is multiplied by 0·8, the product will be the required distance in miles. Details of all W/T fog signals and the method in use are to be found in the *Admiralty List of Wireless Signals* and on page 174.

PASSAGES IN FOG

The following remarks on passages in fog are taken verbatim from *On the Bridge**:

* *On the Bridge*, by Captain J. A. G. Troup, R.N. (Rich and Cowan).

"All passages in fog can and should be divided into one of three types, each requiring its own treatment :

(*a*) Outward bound to the open sea.
(*b*) Point to Point.
(*c*) Inward bound.

"Under (*a*)—Outward bound—we would put a vessel sailing from the Straits of Dover or the Isle of Wight to Vigo, Gibraltar, or America.

"A ship bound from Dover to Plymouth in fog would come under (*b*)—Point to Point—somewhat loosely. A ship bound from the Isle of Wight to the Thames in fog must do point to point all the time.

"Ships bound for Falmouth from New York or for Weymouth from the Channel Islands are examples of (*c*)—Inward bound."

Outward Bound

"Outward bound being the easiest, we deal with it first. Almost regularly—so often every ten years—a definite tonnage of shipping is lost due to failure to act upon the following elementary principle, 'Outward bound don't run aground.'

"If we are approaching narrow waters, *e.g.* Dover Straits, we must know exactly where we are before getting there ; but if a long passage has to be made, *e.g.* to Gibraltar from Dungeness, and if fog is met going down Channel, it is not going to matter much, if at all, either on the passage or when nearing Gibraltar, whether we get our last fix at Dungeness, Beachy Head, or even Ushant. More than one vessel bound, it might be, down Channel for America has been taken in towards the land to listen for a fog signal onshore, and has struck such rocks as the Manacles inside the Lizard. With 500 to 3,000 miles to go, a Captain may well argue as follows : 'I shall be singularly unlucky if I carry this fog all the way, and if I have to go 2,000 miles in fog in the open sea I can only be 2½ per cent. better off than if I go 2,050 miles from my last fix. A fix 2,000 miles from my destination is of little more value at the end of the passage than one obtained even farther away. Hence I shall not risk closing the land at the outset of my voyage ; on the contrary, I shall keep out, and this will keep me clear of some of the traffic as well. If the weather improves, sights will give me an up-to-date fix ; if the fog fails to lift, intense precaution will be as necessary on approaching my destination, whether I have come 500 miles or 2,000.'

"No more need be said regarding the outward voyage, save to remark that if any good fix comes our way, possibly by sounding or W/T D/F, we seize the opportunity : 'comes our way,' be it noted, we have not gone inshore or onshore to look for it.

Point to Point

"We mentioned Dover to Plymouth, and Isle of Wight to the Thames, as examples of point to point. Dover to Plymouth in fog was described as coming somewhat loosely under point to point. A ship so bound, after clearing the Varne Shoal off Folkestone, may sail ten miles or more off the land, until, in order to find Plymouth, the need arises to make Start Point or the Eddystone (figure 54). In deciding whether to navigate in such a manner, or whether to hear each salient fog signal as he passes it, the Captain has to weigh well the advantages of either method. As an old Scots minister once told his flock, 'Beware of your latter end.' The Captain who has steamed down Channel far offshore all night has saved himself much anxiety regarding collision, and his vessel from all risk of

DIAGRAM No. 1.

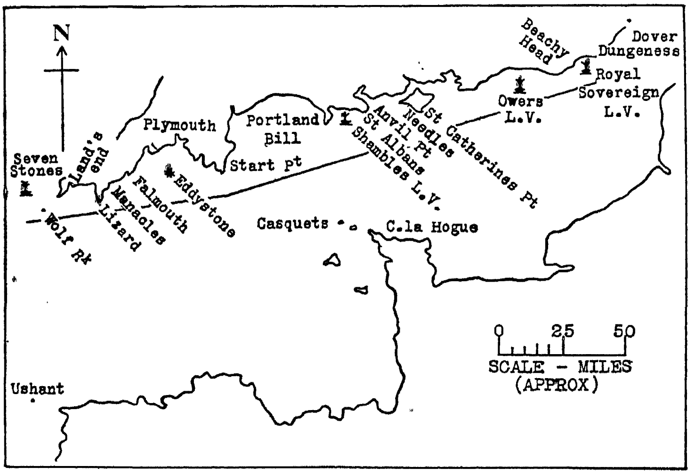


FIGURE 54.

grounding, but when he hauls in to make the Start he has a background of 200 miles D.R. and hence a considerable possibility of error. A man who hears each fog signal as he passes it is in a stronger situation as he approaches Start Point, having heard the Shambles Fog Siren only fifty miles 'ago'; or as he approaches the Eddystone, having heard Start Point only twenty-five miles ago. Point to point, if it can be carried out safely, is generally better navigation; yet it must be allowed that guidance from soundings or W/T D/F may render it unnecessary.

"The other example, namely, Isle of Wight to the Thames, needs few remarks. Point to point must be run all the way as the narrow waters are approached. Soundings, as we will learn, will often help us to see or hear the sea-mark we try to make. We *must* make it or stay to seaward. We can't pass eastward up the Dover Strait

without knowing where Dungeness is, and if we fail off Dungeness and go on, the Varne Shoal, Dover Breakwater, or the Goodwin Sands will not excuse us ; that's all.

If the ship's past history has been satisfactory, the mind is sustained, in those short runs from one fog signal to another, by the knowledge that in clear weather the ship always has made objects on the correct bow—although (being temporarily blind) we insist on a safeguard. The important decision to make is which of the three methods should be adopted—on no account the middle course. The man who plays for a kind of half-hearted safety, steering somewhere between outward bound and point to point, five to seven miles off fog signals doesn't 'get there.' If point to point has been selected, we give ourselves the best chance we can of hearing the fog signals by passing near them. There may be a sea-mark such as the Owers Lightship, which has deep water a mile or more inshore of it, an added reason for steering close to it. Provided the surroundings have been considered, and that our minds are prepared for the possibility, there is *sometimes* nothing disreputable about making such a fog signal ahead or on the 'wrong (outer) bow, for if seeing is believing, hearing, and hearing indubitably, is the next best thing.

Inward Bound

"In order of increasing difficulty, we have now to think of the ship coming in from the sea in fog. What should be in the Captain's mind as he approaches the land ? We have no hesitation in replying : 'I Captain X, shall not grope or blunder in to narrow waters or near danger without adequate precaution.' Having that decision ever in mind, the question will arise : 'How far are we likely to be out of position ? ' If the vessel has only steamed a short distance from the departure fix, say thirty miles, and if the tides and currents are well known, it is reasonable to think that the ship will be not far distant from her estimated position. Yet, even in such a case, we should grasp at a precaution against being caught, unaware, out of reckoning. Knowledge of the probable difference between calculations and reality should be cultivated, and can only be gained by making passages and *thinking about them afterwards*.

"Our precaution may be a W/T D/F bearing ; it is more likely to be got by sounding. Were we coming up Channel from Ushant to the Royal Sovereign Light Vessel off Beachy Head (figure 55), we might well say to ourselves in that anxious hour before we hear the lightship's fog signal : 'If we are ten miles to the west of our estimated position, we will run a few miles, during which we will get soundings of over thirty fathoms ; if we are ten miles to the east, soundings of over thirty fathoms will be obtained for a very short time.' (Note the trend of the thirty-fathom line.) 'If we are late and astern of the estimated position, the ship will cross the twenty-fathom line later than expected ; if we are early and

ahead, the twenty-fathom line will be crossed sooner. This fathom line is obviously a good warning in these waters.'

"In any one (or two) of these eventualities we correct our estimated position by the soundings, and proceed accordingly. Meanwhile no odd hand, please, at the sounding machines. In his navigating days, so urgent did it seem, the writer often took the 'feeler' himself. It takes experience, noticeably with deep soundings, to know when or if the lead has struck bottom. Put a firm downward pressure on the wire by the feeler.

"Another point for the Captain to dwell upon is how the ship is heading compared to the trend of the land or danger line—whether he is steering parallel or at right angles to danger, or closing or opening it. Any of these measures may be necessary, but the course parallel to danger has the merit that a slight alteration will turn

DIAGRAM No. 6. SOUNDINGS IN FATHOMS.

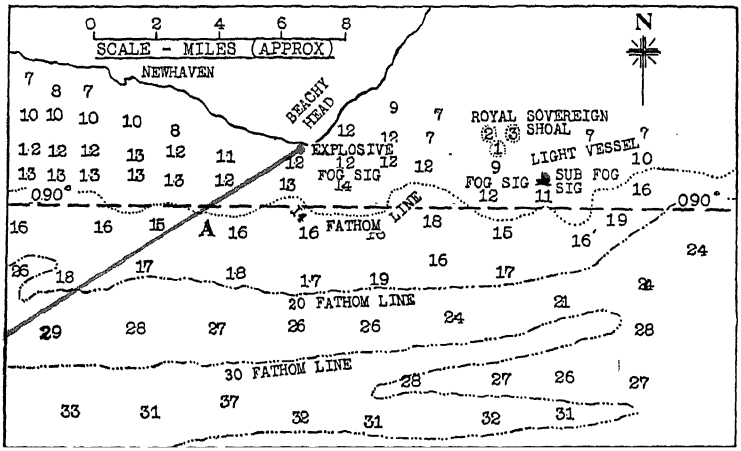


FIGURE 55.

the ship towards safety—a merit unshared by courses which close danger lines at or near right angles. It must be borne in mind that many ships, if steering directly or nearly so towards danger, will, even if the wheel is put hard over, close that danger by an 'advance' of 500 yards or more before beginning to open from it.

"Having ensured that the ship is approaching on the safest available course, we must concoct the best plan for making the fog signal it is hoped to hear. The writer recalls his early efforts, in which a course was steered direct for a fog signal; nothing was heard after running our 'distance,' and no idea remained as to what to do next. One can generally do better than that, and it is suggested that, when groping for a fog signal which is being approached after a long D.R. run it is seldom advisable to steer straight at it. Aim at ensuring throughout the proceeding that the fog signal is:

(*a*) Somewhere ahead and,

(*b*) That you know which side of the ship it is on.

"We have seen the warnings which soundings would give a Captain approaching the Royal Sovereign Lightship; let us follow his fortunes a little farther, supposing him to be bound to the Thames from Ushant. He must know exactly where he is before he reaches the narrow waters east of Dungeness, and it is assumed that he has decided to make the Royal Sovereign Lightship. Now there is no great virtue about the fathom lines printed on the charts. The Captain, provided soundings are plentiful, is quite free to draw one in for his own use. In our diagram (Number 6) a fourteen-fathom line has been inserted by the Captain, because he wants to steam on a line which will lead him safely a mile or two off the lightship. This line is somewhat irregular, but it should serve its purpose. If he passes two miles off the lightship, he thinks he should have a strong chance of hearing the fog siren. He next decided upon the maximum he is likely to be 'out of position,' *i.e.* the amount his reckoning may be wrong. This estimate is important, and is gained by experience and by knowledge of the ship's performance in previous passages. He considers ten miles to be his maximum possible error. (The writer always hoped for an average error, including both distance and direction, of not more than one and a half per cent. of the run, but seldom achieved such good results; he was generally within three miles of his estimated position after running one hundred.) A point 'A' is then selected for which to steer. Point 'A' has to be far enough to the westward to ensure that, even if the ship is out of position to the eastward the full ten miles nevertheless the vessel will hit the fourteen-fathom line westward of the lightship, so that the chance of hearing the fog signal will not be jeopardised. He has continued his fourteen-fathom line away to the westward to see whether, in the event of his being ten miles to the westward of his estimated position, this line will provide a precaution against dangers there. Aided by soundings, the Captain now approaches his fourteen-fathom line, correcting, if he can, his estimated position by the depths obtained.

"The point 'A', in this approach, has a special merit, for a mariner approaching its vicinity has a chance of hearing Beachy Head Fog Signal further, the seaman will be prepared, in addition, to hear his own fog siren echoed off the cliffs. Should this echo be received, his knowledge of the speed at which sound travels in air will give him an estimate of his distance off the land.

"At length, yet with little fear of any unexpected denouement, he strikes his fourteen-fathom line and alters course sharply to 090°. When this alteration has been completed he feels happier, knowing he is steering parallel to his dangers. The lightship, he believes—even knows—to be ahead of him and on his port bow. Sounding is continued, and the fourteen-fathom line is followed by making turns of 20° to 40° in or out, according to the depth obtained. Perfect silence for a time longer than the fog signal's 'period' is ordered on board from time to time. On the telephone in the chart-house

the submarine fog-bell on the lightship is listened for ; the fittings of this installation from the hull upwards require frequent test and overhaul in harbour if they are to serve the ship when needed.

"Working eastward with this procedure, our Captain has run little if any risk, and he would be singularly unfortunate if he failed to hear the lightship.

"We have followed this case through its phases because it exemplifies well how much can be done with soundings. We note that every possible means was harnessed to his use by our Captain—soundings, submarine signals, sirens, silence and even 'safety first.' He made his plan and, with a precaution against surprise from error in any direction, he worked it out. Having 'got hold of' the Royal Sovereign, he may—if he has a visibility of 500 yards—be pictured leaving his fourteen-fathom line to starboard, and edging to port to obtain a sight of the lightship. Thereafter, with but a short run to Dungeness, he will be doing point to point, and he will know that, in a run of only twenty-two miles, he is unlikely to be much out of his course and will steer accordingly—always remembering, as he approaches Dungeness, that he must again take all reasonable precautions.

"In the example just described there was a safeguard for all four (there are only four) of the eventualities : ahead, astern, to starboard and to port of the reckoning. Many occasions arise when all four possibilities need not be, and cannot be countered. A landfall can be envisaged in which we might unwittingly be fifteen miles east or west of our estimated position without endangering the ship, and yet it might be fatal to be three miles ahead of the reckoning. We must select the risks whose results would be distressing, and avoid encountering them without safeguard."

Fog in a Narrow Channel. It will be necessary to work by buoys. Work out the courses from buoy to buoy, allowing for the tidal stream or current and wind, and enter them in the notebook. Always check with great care the type of buoy sighted. When departing from a buoy, work out the accurate time at which the ship should pass and sight the next buoy on the present course and speed. If at the expiration of that time the expected buoy is not sighted, then *stop the ship and anchor, if possible,* because the ship's course has been laid close to the buoys instead of the normal course in mid-channel, and there is thus a very small margin of safety.

TO TURN ON TO A PREDETERMINED LINE

The track proposed for the ship having been decided, it is necessary to allow for the turning circle and to decide on the point at which the wheel should be put over when the course is altered, so that the ship, when steadied on her new course, may be exactly on the pre-arranged track.

This point is found from the *distance to new course* table as explained in Chapter III.

Turning on to a predetermined line is a simple matter if there are suitable shore objects and no tidal stream. For example, in figure 56 a ship steaming a course AB wishes to alter course and make good a course of CD of 280°.

The distance to new course laid back from CD will give the point at which the wheel should be put over. If through this point a line is drawn parallel to the new course, it will be seen to pass through the lighthouse: thus if the ship puts the wheel over when the lighthouse bears 100°, she must be somewhere on the line

TURNING ON TO A PREDETERMINED LINE BY A BEARING.

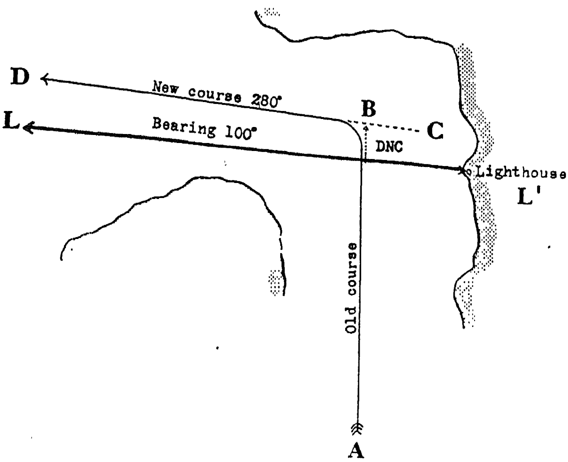


FIGURE 56.

LL′ and will fetch up somewhere on the line CD when steadied on the new course of 280°.

The ideal circumstances in the above example are seldom found in practice, but frequently there is an object available where the principle of the transferred position line can be used in conjunction with the above method, as for instance, if an anchorage is approached on a line of bearing or a transit. The alteration of course to the approach course should then be made on a bearing of the approach object.

Figure 57a shows the small error introduced on reaching the approach course, by using the approach object.

Figure 57b shows the large error which may occur if the object selected is not approximately parallel to the approach course.

Turning on to a Predetermined Line by Time Allowance. In figure 58, a ship steaming ten knots is approaching an anchorage and

steering a course AB. She wishes to anchor in position D on an approach course CD of 003°. There is no tidal stream.

Lay back a distance of EF equal to the distance to new course for the alteration of course, thus obtaining the position for putting over the wheel. Note the accurate time that a known object O bears 003°. When this occurs the ship must be somewhere on the line OG; therefore work out the time the ship will take to steam from OG to HK. (If the distance is one mile, the time interval will be

COMPARISON OF ERRORS WHEN TURNING ON TO A PREDETERMINED ANCHORING COURSE.

SMALL ERROR. BEARING NEARLY PARALLEL TO THE APPROACH COURSE.

LARGE ERROR. BEARING NOT PARALLEL TO THE APPROACH COURSE.

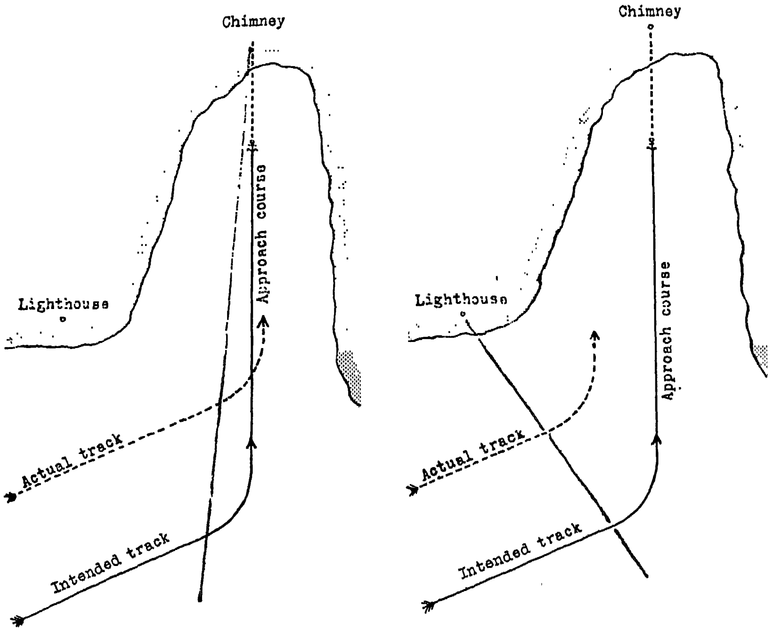


FIGURE 57A. FIGURE 57B.

6 minutes.) On completion of this time interval, alter course to 003°, and the ship should steady up somewhere on the line CD as required.

To Allow for a Current or Tidal Stream. The previous examples made no allowance for the tidal stream. In figure 59, a ship A is making good a course AB. The direction of the ship's head shows the allowance being made to counteract the tidal stream setting to the south-east. The ship wishes to turn to the line CD, and in finding the point G where the wheel must be put over, it is

necessary to make allowance for the tidal stream experienced during the turn. When making good the course CD, the ship will again have to make allowance for the tidal stream and will steer the course shown at X: thus the actual alteration of course will

TURNING ON TO A PREDETERMINED LINE
BY TIME AND BEARING.

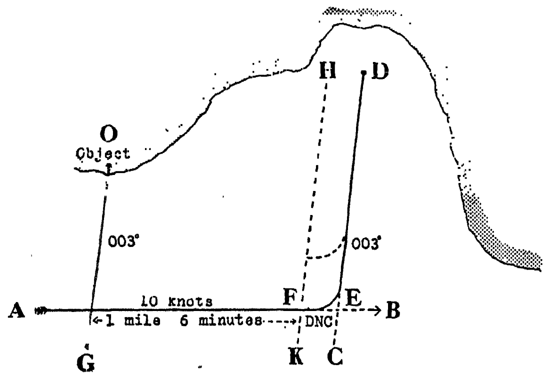


FIGURE 58.

be the difference between the direction of the ship's head at A and at X.

Lay back from C the distance to new course for an alteration of course found from the difference of the ship's head at A and at X.

TURNING ON TO A PREDETERMINED LINE,
ALLOWING FOR A TIDAL STREAM.

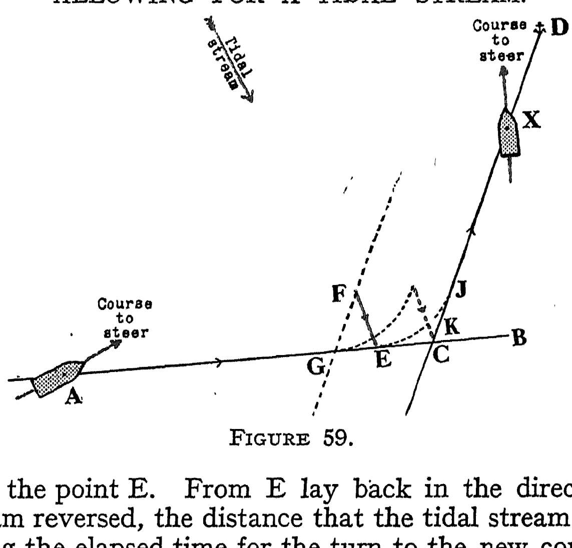


FIGURE 59.

This gives the point E. From E lay back in the direction of the tidal stream reversed, the distance that the tidal stream carries the ship during the elapsed time for the turn to the new course. This gives the point F.

Through F draw FG parallel to the new course CD. The point G will then be the position of the ship when the wheel must be put over.

The ship will thus proceed along a mean course between G and J and will arrive on the line CD at K.

NOTE. The final bearings should be checked because the tidal stream may have been incorrectly estimated.

Regain the line with a BOLD alteration of course.

ANCHORING

Choosing a Position in Which to Anchor. When a position in which to anchor the ship is chosen, numerous factors have to be considered, namely:

1. The depth of water.
2. Whether the bottom is good or bad holding ground. Clay, mud and sand are good holding ground ; shingle, shell and rock are bad holding ground.
3. Whether the anchorage is in a land-locked harbour or an open roadstead.
4. The strength and direction of the prevailing wind. If possible, anchor on the weather shore and so have a lee with room to drag.
5. The direction and strength of the tidal stream.
6. The rise and fall of the tide.
7. The length and draught of the ship.
8. The proximity of landing places.
9. The proximity of adjacent ships.
10. The amount of cable to be veered. This will depend on the nature of the bottom, the weather, length of stay, etc. but should *not be less than three times the depth of water*, except when it is necessary to anchor in very deep water. A rough rule for an emergency is that the number of shackles of cable should equal the depth of water in fathoms divided by two.

    When in doubt allow an extra shackle or more and thus avoid any possibility of the ship's dragging because insufficient cable has been veered.
11. The proximity of dangers. It is impossible to give any definite rule about how near a danger a ship may be anchored, but an ample margin of safety should be allowed in expectation of bad weather and the ship dragging her anchors. At single anchor it is usual to allow a safety margin equal to the amount of cable to be veered plus the length of the ship plus one cable.

Always try to anchor stemming the wind or tidal stream, whichever is the stronger. It needs a strong wind to produce a greater effect on the ship than a tidal stream of ½ knot.

Come to with the weather anchor, except in places where the tidal stream or current are so strong that the ship will lie easier if the lee anchor is let go.

TO ANCHOR A SHIP IN A CHOSEN POSITION

1. Choose a conspicuous mark ashore, as for example, the church in figure 60, the line of bearing of which, passing through the chosen

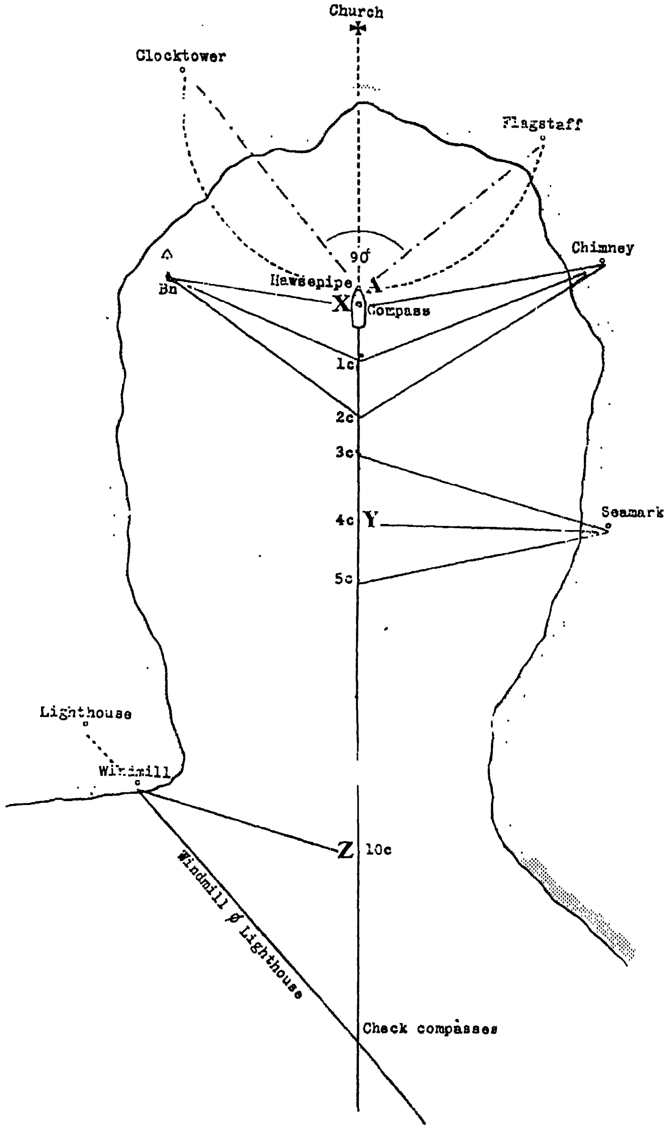


FIGURE 60.

position, clears all dangers. This is the line of bearing on which to approach.

2. From A, the position of the anchor, lay back AX, the distance

from the stem to the standard compass. X will be the position of the standard compass on letting go.

3. From X lay off a position line to some conspicuous object, as for example, the chimney, such that it makes an angle of nearly 90° with the line of approach. If there is no object near the beam, the position line may be the arc of a circle through two points, one on each bow. The objects should then be close, and the angle subtended at X as large as possible. This would occur if the only objects available were the flagstaff and the clocktower.

4. The speed of the ship must be reduced before anchoring, so that when the engines are reversed, on letting go the anchor, the way is taken off the ship with no strain on the cable. The distances at which to make this reduction of speed vary with different types of ships.

5. Suppose that the ship reduces speed at one mile and stops engines at four cables from the anchorage. From X lay back along the line of approach, XZ, equivalent to one mile. Then Z is the point at which to reduce speed. Lay back XY, equivalent to four cables, and Y is the point at which to stop engines. The instant of arrival at Y and Z is found by bearings or horizontal angles in a similar way to finding the time of arrival at position X.

6. If there is a cross stream, the course must be adjusted to make good the line of approach. The effect of the cross stream will increase as the ship loses headway. This is particularly important in heavy ships which may have to stop their engines seven cables before letting go the anchor.

7. Turn on to the line of approach as soon as possible, to give plenty of time to get the ship steady on the line of bearing. A good plan if running in on an object is to make a note against the approach course in the notebook.

Bearing *more*, ship to *port*.
,, *less*, ,, ,, *starboard*.

This will apply only to gyro bearings.

8. If the ship is set off the line of bearing, regain the line with a bold alteration of course.

9. Bear in mind, in ships with a long forecastle, that the ship's head must be the same as the bearing of the line of approach on letting go, otherwise, although the bridge may be at X, the anchor will not be at A.

10. Have alternative objects and bearings ready because the selected objects may be obscured.

11. Have all data, objects, bearings, etc., written down in the notebook, so as to avoid having to keep looking at the chart.

ANCHORING ON A SHIP ALREADY AT ANCHOR

The ship that is to be anchored on, hoists:

1. her pendants.

2. the bearing and distance of her anchor from the foremast, which can be found by:

(*a*) a compass bearing and range of the anchor buoy by small rangefinder.

(*b*) a compass bearing and an angle of depression of the anchor buoy.

(*c*) a compass bearing and an angle of elevation from the anchor buoy.

(*d*) fixing the bridge and measurement on the chart.

3. the amount of cable veered.

At night she shows position lights and a white light at the masthead.

Example. A ship A, shown in figure 61, is ordered to anchor 112°–2 cables from a ship C, which signals the bearing and distance of her anchor as 135°–0·5 cables. A's stem to standard 90 feet.

Place C's foremast in the centre of the mooring board, as shown in figure 61, and plot the position of her anchor, 135°–100 yards, from this position.

From the position of C's anchor plot the position of A's anchor, 112°–2 cables.

Decide on the approach course and lay back this course from the anchor berth.

Lay back a distance of 90 feet from the position of A's anchor. This gives the position of A's standard compass on letting go.

From this position lay back distances of 1, 2, 3 cables, etc., and take off the bearing and range of C's foremast for each point.

Make allowance for any tidal stream or current.

Arrange to turn on to the approach course on a range and bearing of C's foremast. Then by frequently fixing the ship's position by range and bearing, alter course a few degrees, as necessary to keep on the line the whole way up the approach course.

Let go by range or bearing, whichever is changing more rapidly.

To Anchor at a Definite Time without Altering Speed. It is always desirable to anchor the ship at the correct or advertised time, and it is well to remember that an increase or decrease of speed will cause inaccuracies which do not occur when course is altered.

The following simple method of dealing with this problem enables:

1. the chart to be prepared beforehand.
2. the navigator to see at a glance, whenever he fixes the ship's position, whether he is ahead or astern of time.

3. last minute alterations of speed to be avoided.

Example. A ship has signalled her time of anchoring at a position A, shown in figure 62, as 0800. She proposes to approach the anchorage on a course 180°.

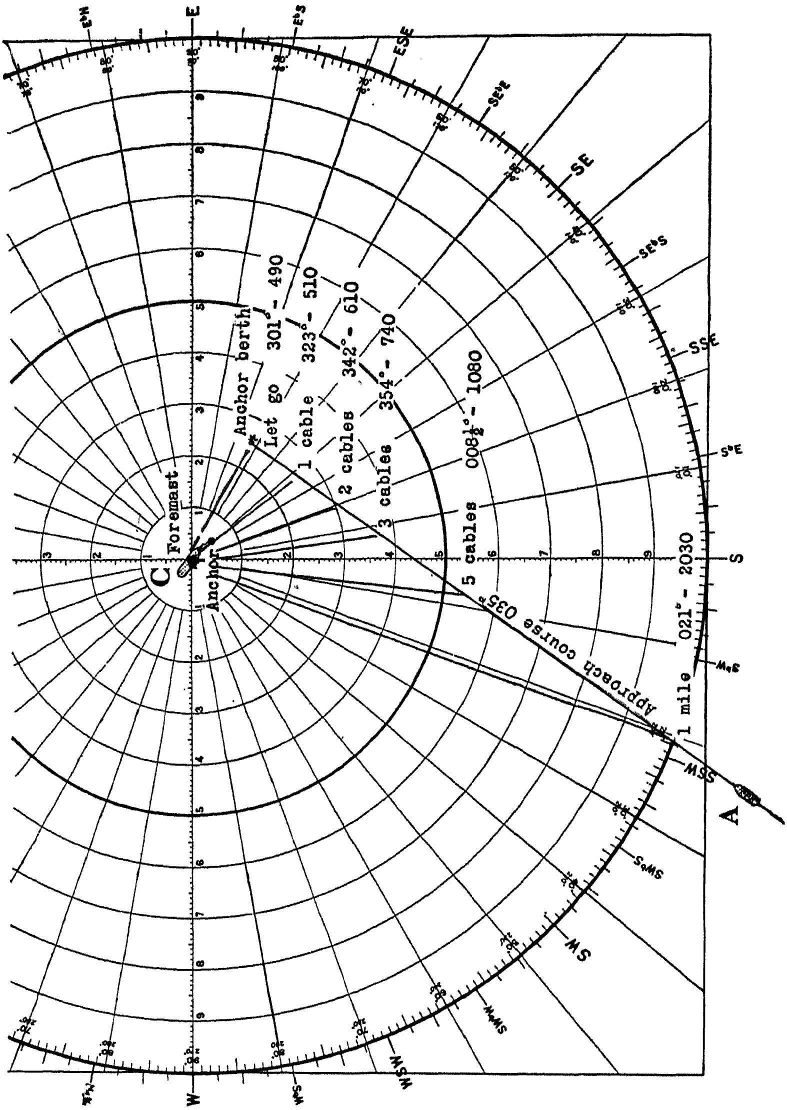


FIGURE 61.

Her speed of approach will be 12 knots, and will not be altered until the engines are stopped at 3 cables from position A.

To Prepare the Chart, calculate the distance the ship will run in the 10 minutes prior to anchoring, making allowance for stopping

engines 3 cables from A. Lay back this distance, AB, along the line of approach. B is the position to be attained at 0750.

Since 5 minutes at 12 knots is equivalent to one mile, with centre B lay back 5-minute time circles. The chart is now prepared, and at 0710 the ship, steering 270° speed 12 knots, fixes her position at F.

At 0715 she is in position E, inside the 0715 circle. Similarly at 0720 she is at D inside the 0720 circle, but it is seen that at 0725

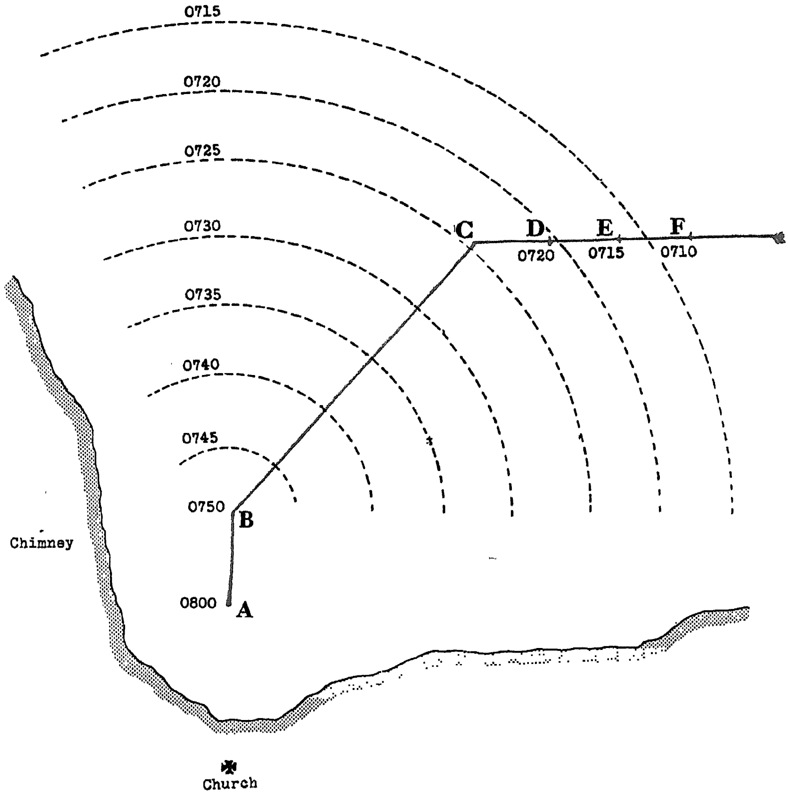


FIGURE 62.

she will arrive at C on the 0725 circle, at which time it will be necessary to steer the course CB to arrive at B at 0750.

NOTES ON ANCHORING

1. Prepare the anchor plan beforehand.

2. The most satisfactory plan is to approach on a transit and to let go the anchor on an object abeam.

3. It is unusual to find a convenient transit and the next most satisfactory plan is to approach with an object ahead.

NOTE. When the ship is on the correct line with an object ahead, it frequently happens that a tree or house is seen to be in transit with the chosen object.

4. Frequently it is not possible to have any object ahead, in which event the ship will have to be fixed all the way along her approach course.

5. When altering course to the approach course, remember that the bearing of the object on which it is proposed to alter course must be as near as possible parallel to the approach course, as shown in figure 57.

6. During the approach, if the ship is found to be off the line, there is always a danger of altering course the wrong way. This danger can be avoided by stating clearly in the notebook, against the approach course, the manner in which the bearing will alter according as the ship is to starboard or port of the line.

7. It may not be possible to identify the chosen objects : therefore get on the line of approach as early as possible and identify the objects as soon as possible by 'cutting in'. Always lay off and note the approach bearings of several objects, any one of which may serve instead of the original choice.

8. When approaching an anchorage, always make sure that the anchor berth and line of approach are clear of other ships.

Check the position of any ship suspected of fouling the anchor berth by:

(*a*) fixing your own position and plotting the other ship by range and bearing.

(*b*) by taking a bearing of the other ship when it is in transit with a charted shore object and so obtain a position line on which the other ship must lie. This should be done as early as possible and before altering to the approach course, so that a second position line may be obtained by observing a bearing of the ship in transit with another charted shore object. The position of the other ship will then be fixed as shown in the following example.

A ship, shown in figure 63, steering 080° and intending to anchor in position Z, approaches the anchorage on a course 350° and suspects that a ship D is foul of it. At 1100 the suspected ship is observed in transit with a chimney bearing 050°.

At 1125 the suspected ship is observed in transit with a flagstaff bearing 024°.

Thus D's position can be plotted on the chart, but remember that the position of D's anchor will have to be estimated, after allowance has been made for the wind and tidal stream or current at the time.

9. If there is no accurate chart of the anchorage or if the safety of the ship is in doubt, take careful soundings within a radius of at least 3 cables of the ship to make certain there are no uncharted rocks or dangers. (K.R. & A.I. Art. 1165.)

MOORING

To Moor a Ship in a Selected Position. When a ship is moored, the same principles apply as for anchoring with the following exceptions.

1. It is first necessary to decide the length of cable on each anchor when the ship has been moored. As a general rule the amount of cable for a heavy ship is six shackles on each anchor. As explained in the *Seamanship Manual*, one shackle of cable is usually required to go round the bows so that the mooring swivel may be shackled on. The distance between the two anchors, when let go, is therefore $[(6\times2)-1]$ or 11 shackles. A shackle of cable equals 25 yards; therefore the distance of each anchor from the

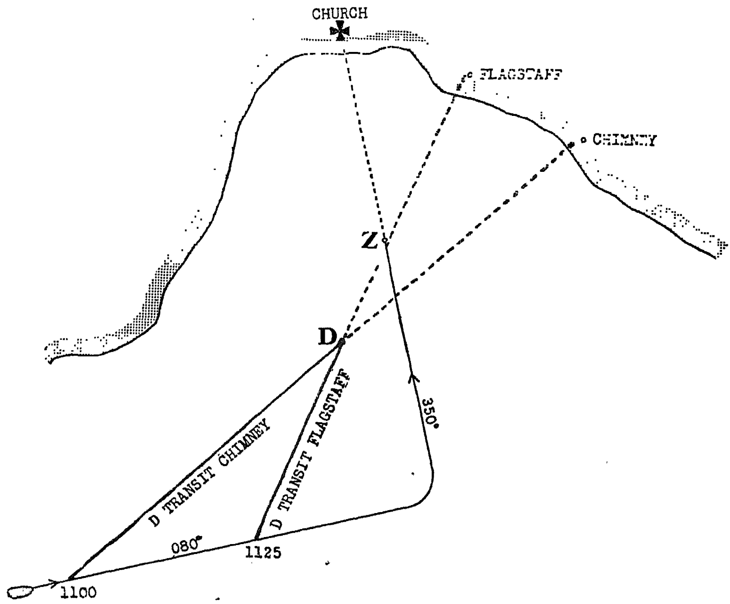


FIGURE 63.

point 'A' should be $\frac{1}{2}(11\times25)$ or $137\frac{1}{2}$ yards. This allowance does not vary appreciably with the depth of water.

2. The direction of the line joining the anchors should coincide, when possible, with that of the prevailing wind or tidal stream, and each anchor should be sufficiently far from dangers, and from the anchors of other ships, to enable it to be weighed without inconvenience, whatever the direction of the wind may be.

Points to bear in mind.

1. Reduce speed so that the cable on the 1st anchor is laid out straight and the way taken off the ship as the 2nd anchor is let go.
2. The 2nd anchor is usually let go from the forecastle unless the ship is in a well-charted harbour with objects on the beam close to the ship.
3. Let go the weather anchor first in order to keep the cable clear of the stem when middling.

4. The ship's head must be kept steady while the first cable is being laid out.

5. Take care, when choosing the berth, that the ship has swinging room around both anchors, as otherwise the wind may make it impossible to unmoor.

6. Always avoid excessive strain on the cables.

7. Remember that the stem of the ship will fall to leeward of the line of anchors when lying at open hawse.

Example. A ship, shown in figure 64, is ordered to moor with 5 shackles on each anchor in position A. Stem to standard 100 feet.

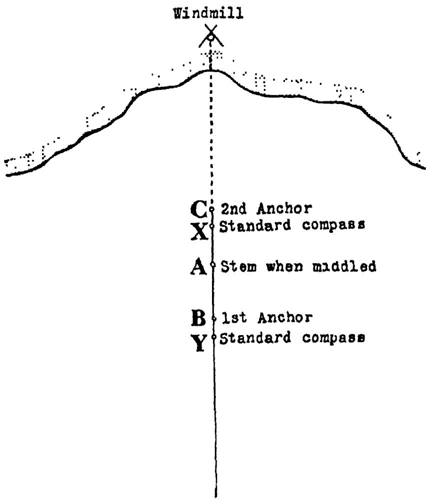


FIGURE 64.

It is decided to run in with the windmill ahead on a line of bearing. This line of bearing will be the 'line of anchors' when the ship is moored.

From A lay off $AB = AC = \frac{(2\times5)-1}{2} \times 25$ yards$=112\frac{1}{2}$ yards.

B and C will be the positions of the 1st and 2nd anchors.

From B and C lay back distances of 100 feet to Y and X.

Y is the position of the standard compass at the moment of letting go the first anchor.

X is the position of the standard compass at the moment of letting go the second anchor.

The moment of arrival in these positions can be found either by beam bearings or by horizontal angles between objects on the bow, as for anchoring.

Mooring on a Ship Already Moored. The ship to be moored on hoists :

1. a compass signal to show the direction of the ship's head.

2. a bearing signal to show the direction of the line of anchors.
3. two numeral groups showing the number of shackles out on each anchor.
4. at night, a white masthead light and position lights.

MOORING ON A SHIP ALREADY MOORED

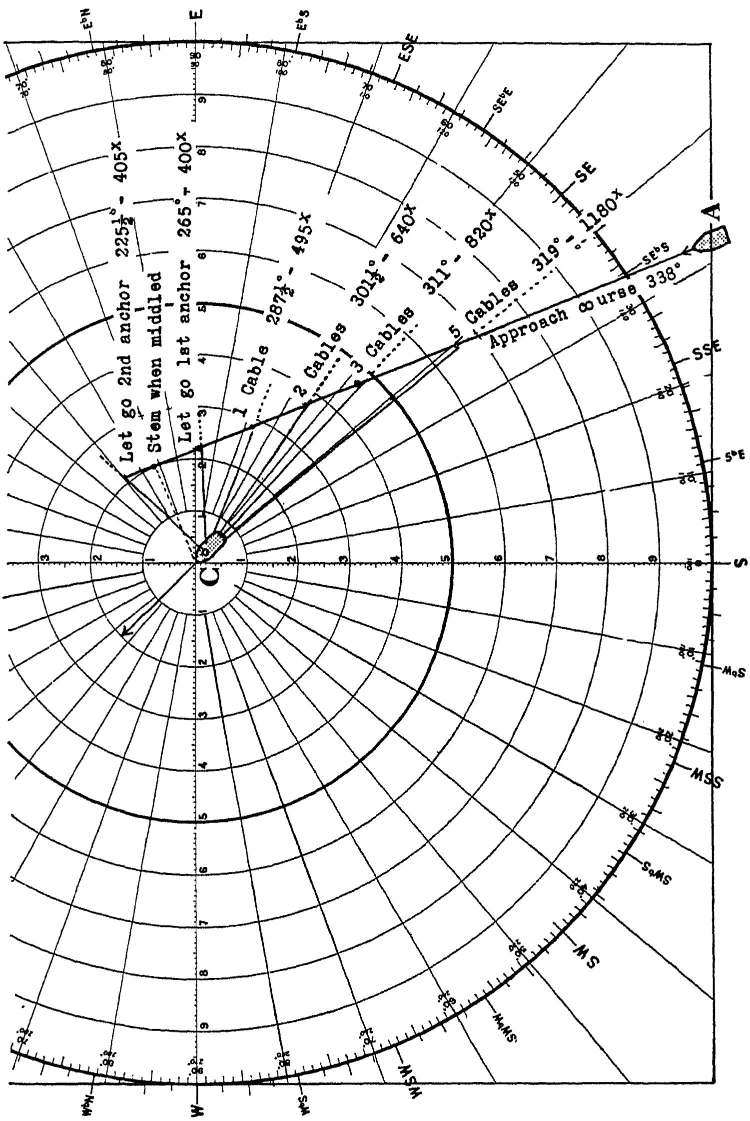


FIGURE 65.

Example. A ship A, shown in figure 65, is ordered to moor in a position 067°–2 cables from a ship C that signals:

Ship's head 315°.
Line of anchors 158°.
6 shackles of cable on each anchor.

A's stem to standard=90 feet.
C's stem to foremast=120 feet.
It is decided to approach from the south.

Place C's stem in the centre of the mooring board and plot the position of her foremast. From the centre of the board lay off the distance, 2 cables–067°. This gives the position of A's stem when middled. Through this position draw the line of anchors 338°–158°. 338° will be the approach course. Plot the positions of A's anchors at a distance $\frac{1}{2}[(2\times6)-1]\times25$ or $137\frac{1}{2}$ yards, each side of the stem when middled.

Plot back from the position of the anchors the distance of A's stem to standard (90 feet), and thus obtain the position of A's standard compass for letting go the 1st and 2nd anchors.

Lay back distances to determine the positions for reducing and stopping, and take off the bearings and distances of C's foremast, as shown in the figure.

Knowing C's length, and the direction of her ship's head, plot her stern. This may give a better cut for bearings when the anchors are let go.

Let go by range or bearing, whichever is changing more rapidly.

CONNING THE SHIP

1. The order *port* or *starboard* should always be followed, after a short pause, by the number of degrees of wheel required.
2. Avoid using the order *hard a-starboard* and *hard a-port*. The rudder should not be put over more than 30° except in emergency.
3. When a course is given to the helmsman, the order *steady* should be used. *Steady* does not necessarily mean that the wheel is to be put amidships. It directs the helmsman to keep the ship in the direction she is heading when the order is given. The helmsman should at once report the direction of the ship's head by his compass and give the necessary wheel to keep the ship's head in this direction, or, if she has swung off the heading, to bring her back.
4. The order *meet her* should not be used.
5. When small alterations of course are made, it is usual to name the course to be steered, instead of conning the ship onto it.
6. Orders such as *starboard a point* should never be given.
7. If the ship is off her course, do not say *You are* 3° *to starboard of your course*, but *You are* 3° *to the northward*, etc., and with a gyro *You are* 3° *high or low*.
8. Never give the order *steady* when the ship is swinging fast.
9. If interrupted during an alteration, tell the quartermaster to steer a definite course.
10. If the ship is being conned from forward, a movement of the ship's head will be most noticeable by looking aft.

11. When steering on a leading mark, always steady on a course. If the ship fails to keep on a mark, the course should then be adjusted.

12. The moment to give the order *amidships* and put on opposite wheel varies with different classes of ships, and with the wind, and every O.O.W. should always know the rules for his particular ship.

Example of an Alteration of Course to Port

O.O.W. '*Port twenty.*'
Q.M '*Port twenty. . . . Twenty of port wheel on, sir.*'
O.O.W. '*Ease to ten.*'
Q.M. '*Ease to ten . . . Ten of port wheel on, sir.*'
O.O.W. '*Midships.*'
Q.M. '*Midships. . . . Wheel's amidships, sir.*'
O.O.W. '*Starboard ten.*'
Q.M. '*Starboard ten. . . . Ten of starboard wheel on, sir.*'
O.O.W. '*Midships.*'
Q.M. '*Midships. . . . Wheel's amidships, sir.*'
O.O.W. '*Steady.*'
Q.M. '*Steady. . . . Course* 228°, *sir.*'

NAVIGATION IN CANALS

All passages through canals must conform to local regulations, and the navigator should read beforehand and have on the bridge all available publications concerning the place.

Enter in the notebook beforehand :

1. the tidal stream or current expected.
2. the various local signals.
3. the marks to be expected.

In the Suez Canal it has been proved by experiment that the water level is lowered 1·5 feet when a ship proceeds at $5\frac{1}{2}$ knots. This point must be noted when the draught clearance is considered.

When a twin-screw ship sheers to port in a canal, control will best be regained by keeping the port screw going half speed or more ahead, with the rudder set against the sheer and the starboard screw going slow ahead, rather than astern. Experiments show that going astern produces an opposite sheer which cannot be controlled by the rudder, because steerage way is lost. A sheer to starboard requires the reverse procedure.

NAVIGATION IN CORAL REGIONS

If the charts are inadequate it is necessary to navigate by eye with extreme caution.

Always place lookouts aloft and on the forecastle, and proceed at a speed sufficiently slow to enable soundings to be taken.

Coral can Best be Seen

1. when the Sun is high in the heavens.

2. when the Sun is astern.

3. when there is sufficient breeze to ruffle the water; in a glassy calm it is often difficult to distinguish reefs.

4. from the masthead; under favourable circumstances a bank with 3 or 4 fathoms of water over it can be seen at the masthead from a fair distance.

Passing an Unsurveyed Reef. Keep to the weather side because any detached pinnacles will be shown by the sea's breaking over them. Coral usually grows to windward and is steeper on the side of the prevailing wind.

Coloration of Reefs. Reefs having 3 feet of water over them appear a light brownish colour.

Reefs having 6 feet of water over them appear a clear green. As the depth increases the colour deepens to dark green and finally becomes, when the depth is out of soundings, a deep blue.

THE UNIFORM SYSTEM OF LIGHTS

Full information is given in the introductory remarks in the *Light Lists*. (See page 33.)

Details of Lights are Given

1. On Admiralty charts. The large scale charts are the most reliable source of information.

2. In the *Light Lists*. These include information not given on the charts, for example, details of the building, etc.

3. In the *Sailing Directions*. Only the height and description of the buildings are given.

The lights themselves may either show a continuous steady light or be varied by flashes, eclipses, etc.

They are divided into two types:

(*a*) lights which do not change colour throughout the entire system of changes.

(*b*) lights which change colour.

Notes on Lights

1. A light 'Alt.Fl.W.R.', when seen from a given position will show alternate single flashes of white and red.

2. The *period* of a light is the interval between successive beginnings of the same phase.

For example, the period of a flashing light is the interval between the beginning of one flash and the beginning of the succeeding flash. With an alternating, occulting, or group flashing light, etc., the period is the time occupied by the exhibition of the entire system of changes included in the same phase.

3. (U) after the name of a light indicates that it is unwatched and must not therefore be implicitly relied on.

4. The height of a light is the distance between the centre of the lantern and the mean high water spring level.

TABLE OF LIGHTS

Lights, the colour of which does not alter when viewed from a given position	Characteristic phases	Lights which alter in colour when viewed from a given position
F.—Fixed.	A continuous steady light.	Alt.—Alternating.
Fl.—Flashing.	(*a*) Showing a single flash at regular intervals, the duration of light being always less than that of darkness. (*b*) A steady light with, at regular intervals, a total eclipse, the duration of light being always less than that of darkness.	Alt.Fl. — Alternating flashing.
Gp.Fl.—Group flashing.	Showing, at regular intervals, a group of two or more flashes.	Alt. Gp. Fl.—Alternating group flashing.
Occ.—Occulting.	A steady light with, at regular intervals, a sudden and total eclipse ; the duration of darkness being always less than, or equal to, that of light.	Alt.Occ.—Alternating occulting.
Gp.Occ.—Group occulting.	A steady light with, at regular intervals, a group of two or more sudden eclipses.	Alt.Gp.Occ.—Alternating group occulting.
F.Fl.—Fixed and flashing.	A fixed light varied, at regular intervals, by a single flash of relatively greater brilliancy. The flash may or may not be preceded and followed by an eclipse.	Alt.F.Fl.—Alternating fixed and flashing.
F.Gp.Fl.—Fixed and group flashing.	A fixed light varied, at regular intervals, by a group of two or more flashes of relatively greater brilliancy. The group may or may not be preceded and followed by an eclipse.	Alt.F.Gp.Fl. — Alternating fixed and group flashing.

VISIBILITY

The figures indicating the visibility of the various lights are those for a dark clear night and a height of eye of 15 feet.

In practice, visibility may be altered by refraction, weather, the height of the tide, and the difference between the actual height of eye and 15 feet.

Stevenson's Table of Distances. This table is given in the introductory remarks to the *Light Lists* and affords a ready means of finding the visibility in clear weather :

1. of all lights where the height of eye of the observer is other than 15 feet.
2. of powerful lights the range of which exceeds the visibility given in Admiralty publications.

NOTE. To avoid having to refer to this table every time a light is sighted, it is a good plan to work out from the table the difference between the distance of the horizon for the compass platform and for a height of 15 feet and so obtain a constant, which, if added to the visibility of the light given in the *Light Lists* or on the chart, will quickly give the distance at which the light should be sighted from that compass platform, if it is sufficiently powerful to be visible. The constant should be entered in the notebook.

Notes on Visibility

1. At short distances, flashing lights usually show a faint continuous light between flashes.
2. Haze and distance may reduce the apparent duration of a flash.
3. In determining the probability of sighting a light in haze, consider the power.
4. The glare of lights is sometimes seen at great distances.
5. Lights placed very high—lights, for example, on the Spanish coast—are often obscured by cloud.
6. The distances given on the chart may sometimes be a mile or two in error.

Bearings of Lights. The *Admiralty Light Lists* give *true bearings* of lights *from seaward*, measured in degrees from 000° to 360°, clockwise.

The sector limits and arcs of visibility are always arranged from left to right.

SECTORS

Variations in the atmosphere sometimes cause white lights to assume a reddish hue. The observer should, therefore, not trust solely to colour where there are sectors, but must verify the position by taking a bearing of the light.

On either side of the line of demarcation between white and red, and also white and green, there is always a small sector of uncertain colour. The edges of a sector are seldom cut off sharply,

especially when the observer is close, and the light often fades gradually away after the line given as the sector limit has been crossed.

When the light is cut off by adjoining land, and the arc of visibility is given in the *Light Lists* or chart, remember that the bearing on which the light disappears will frequently vary with the :

1. distance of the ship.
2. height of the eye of the observer.
3. slope of the land.
4. height of the tide.

EXHIBITION OF LIGHTS

Lights are shown as follows :

In Clear Weather

Lights under the jurisdiction of Trinity House Northern Lights Board Commissioners of Irish Lights	Sunset to sunrise.

In Foggy or Hazy Weather

Lights under the jurisdiction of Trinity House Commissioners of Irish Lights	1 hour before sunset to 1 hour after sunrise.
Northern Lights Board.. ..	According to the weather.
Clyde Lighthouse Trust ..	Shown during the day.

LIGHT-VESSELS

The following remarks refer to light-vessels off the coasts of the British Isles. Information concerning foreign light-vessels is given in the *Sailing Directions* and *Light Lists*.

1. Light-vessels are painted *red* in England and Scotland and *black* in Ireland. Names are printed, in white letters, on their sides.

2. The *height* given in the *Light Lists* is the distance from the water level to the centre of the lantern.

3. A white light is shown from the fore stay, 6 feet above the rail, to show the direction in which the vessel is swung.

4. When a light-vessel is off her proper station, the day mark is struck; the characteristic light is not shown and the characteristic fog signal will not be sounded. In addition :

By Day a large black ball is hoisted at each end of the vessel. She also flies the International signal ' PC '.

By Night a fixed red light is shown at each end of the vessel. A red and a white flare are burned simultaneously every 15 minutes, or alternatively in place of flares, a red light and a white light are shown simultaneously.

5. If, for any reason, the light-vessel is unable to show her usual characteristic light while on her station, the riding light only will be shown.

6. If, in a fog, traffic appears likely to collide with the light-vessel, the ship's bell will be rung rapidly in the intervals between sounding the normal fog signal. If the normal fog signal is made by hand horn, the period of the signal is shortened as shipping approaches and may eventually be a continuous signal until there is no danger.

7. 'J D' International ("You are standing into danger") may be hoisted by a light-vessel. If so, attention is called to it by the firing of a gun or rocket, repeated at short intervals until observed.

8. Light-vessels make various distress signals either for themselves or for other ships. Full details of these signals are given in the *Light Lists*.

NOTE. Remember that light-vessels may be withdrawn for repairs without notice, and sometimes they are not replaced by relief vessels.

UNIFORM SYSTEM OF BUOYS ROUND THE BRITISH ISLES

The term *starboard hand* means that side of the channel which will be on the right hand of the navigator when he is going with the main stream or flood tide, or when entering a harbour or river from the seaward.

The term *port hand* means that side which will be on the left hand in the same circumstances.

The direction of the main flood stream round the British Isles is shown in figure 66.

Progress of the Main Floodstream

1. *Towards the Thames Estuary.* In the region of the English Channel; north and east coasts of Great Britain (excluding Moray Firth, Firth or Forth and the Wash); Pentland Firth and between Orkneys and Shetlands.

2. *Towards the Solway Firth on the east and Loch Strangford on the west.* In the region of St. George's Channel and the Irish Sea (excluding the Bristol Channel); north coast of Ireland (Tory Island to Rathlin Island) and the south coast of Ireland from Skelligs Rocks to Carnsore Point.

3. *To the north.* On the west coast of Ireland from Skelligs Rocks to Tory Island.

4. *Towards Cape Wrath.* On the west coast of Scotland north of the Mull of Cantyre, including the Hebrides.

5. *To the south.* On the east and west coasts of the Orkneys and Shetlands.

Information Concerning Buoys

1. The best guide is the largest-scale chart of the place concerned.
2. Details of buoys *may* be given in the *Sailing Directions*.
3. Light buoys are *not* mentioned in the *Light Lists*.

THE DIRECTION OF THE MAIN FLOOD STREAM AROUND THE BRITISH ISLES.

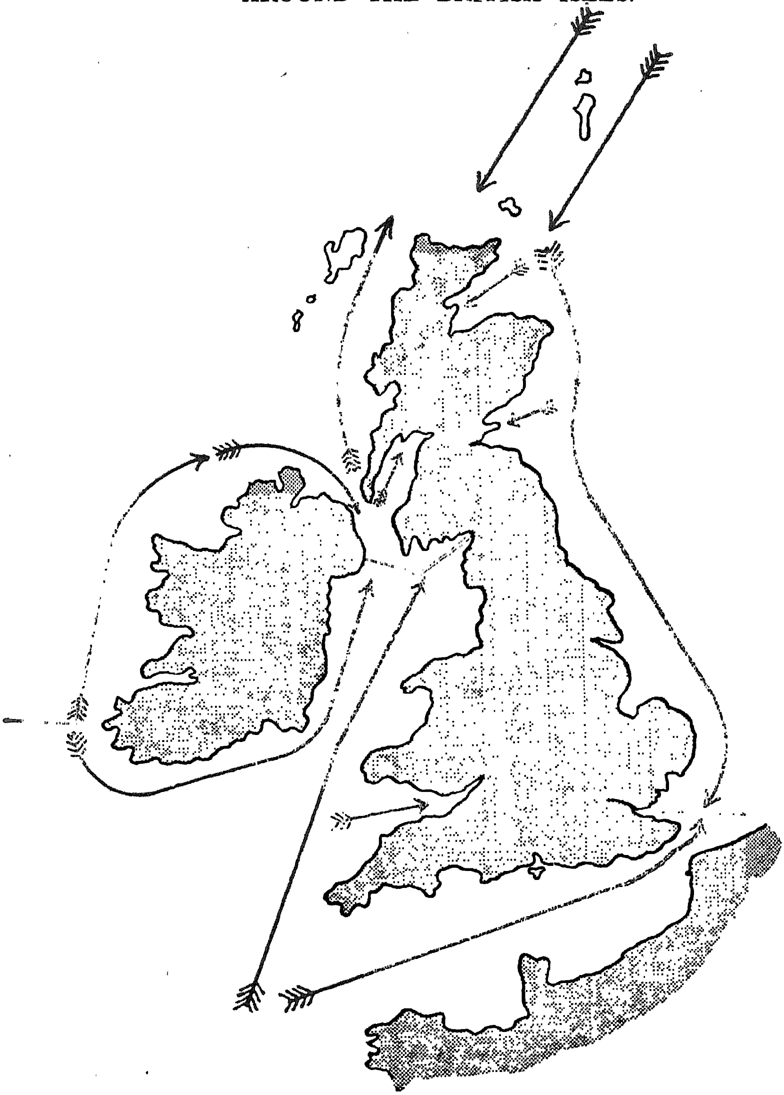


FIGURE 66.

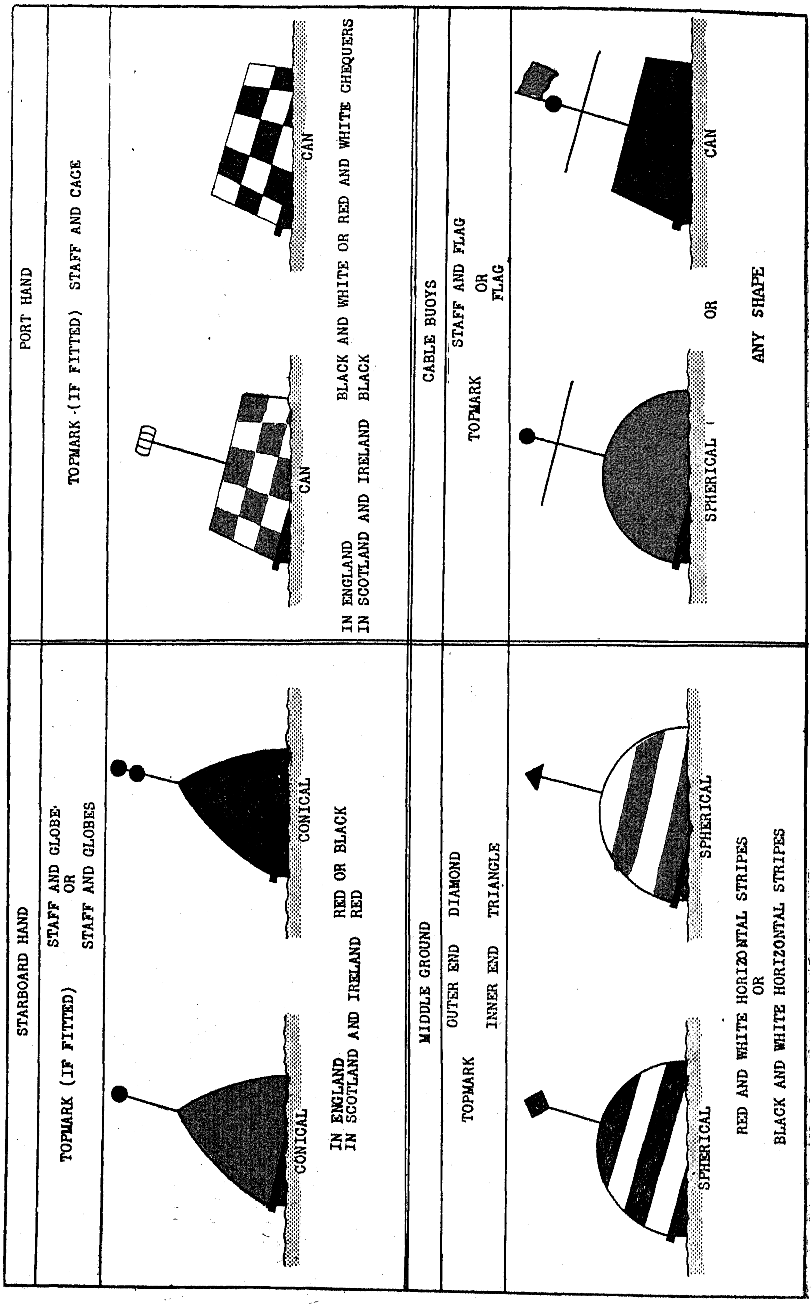
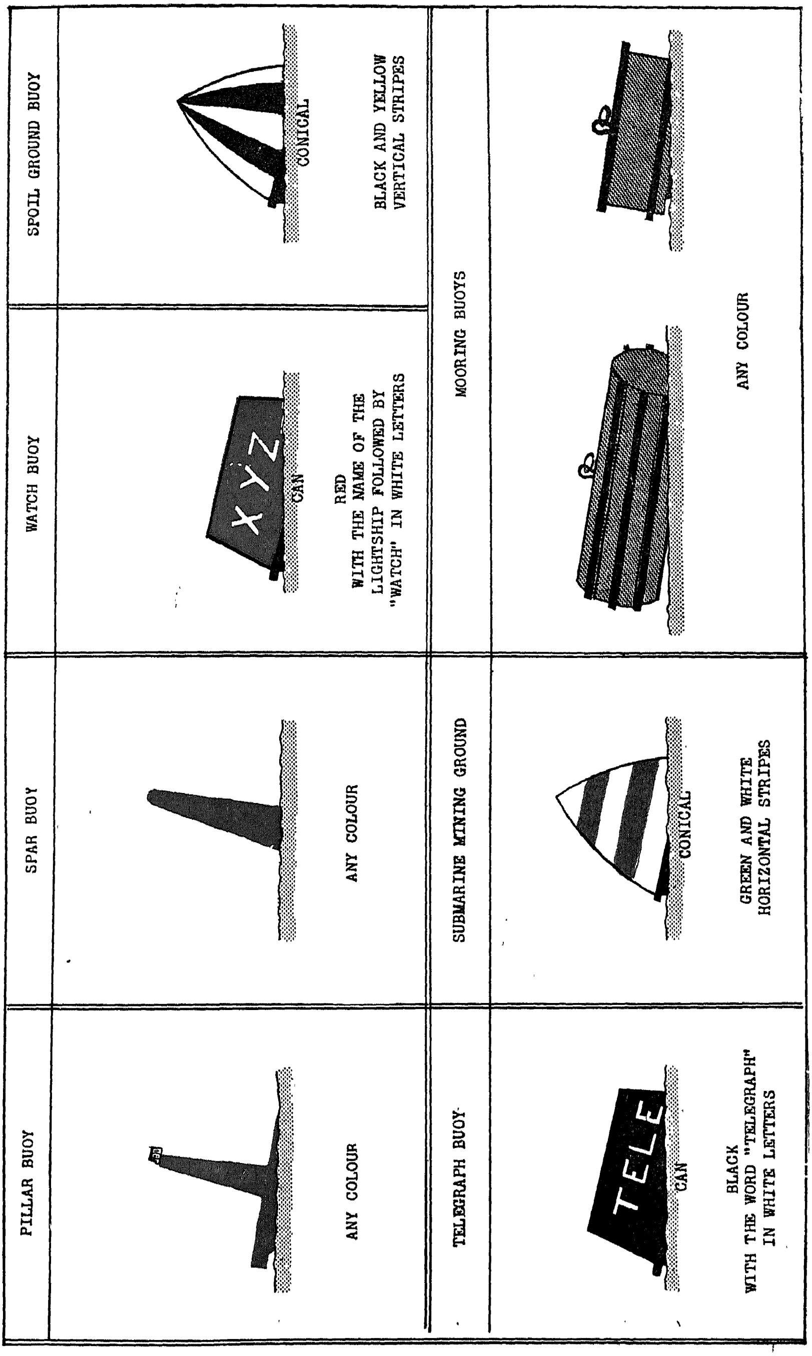

STARBOARD HAND
TOPMARK (IF FITTED)
STAFF AND GLOBE
OR
STAFF AND GLOBES
CONICAL
CONICAL
IN ENGLAND
IN SCOTLAND AND IRELAND
RED OR BLACK
RED
PORT HAND
TOPMARK (IF FITTED) STAFF AND CAGE
CAN
CAN
IN ENGLAND
IN SCOTLAND AND IRELAND
BLACK AND WHITE OR RED AND WHITE CHEQUERS
BLACK
MIDDLE GROUND
TOPMARK
OUTER END DIAMOND
INNER END TRIANGLE
SPHERICAL
SPHERICAL
RED AND WHITE HORIZONTAL STRIPES
OR
BLACK AND WHITE HORIZONTAL STRIPES
CABLE BUOYS
TOPMARK
STAFF AND FLAG
OR
FLAG
SPHERICAL
OR
CAN
ANY SHAPE

FIGURE 67.


PILLAR BUOY
ANY COLOUR
SPAR BUOY
ANY COLOUR
WATCH BUOY
XYZ
CAN
RED
WITH THE NAME OF THE
LIGHTSHIP FOLLOWED BY
"WATCH" IN WHITE LETTERS
SPOIL GROUND BUOY
CONICAL
BLACK AND YELLOW
VERTICAL STRIPES
TELEGRAPH BUOY
TELE
CAN
BLACK
WITH THE WORD "TELEGRAPH"
IN WHITE LETTERS
SUBMARINE MINING GROUND
CONICAL
GREEN AND WHITE
HORIZONTAL STRIPES
MOORING BUOYS
ANY COLOUR

GURE 68

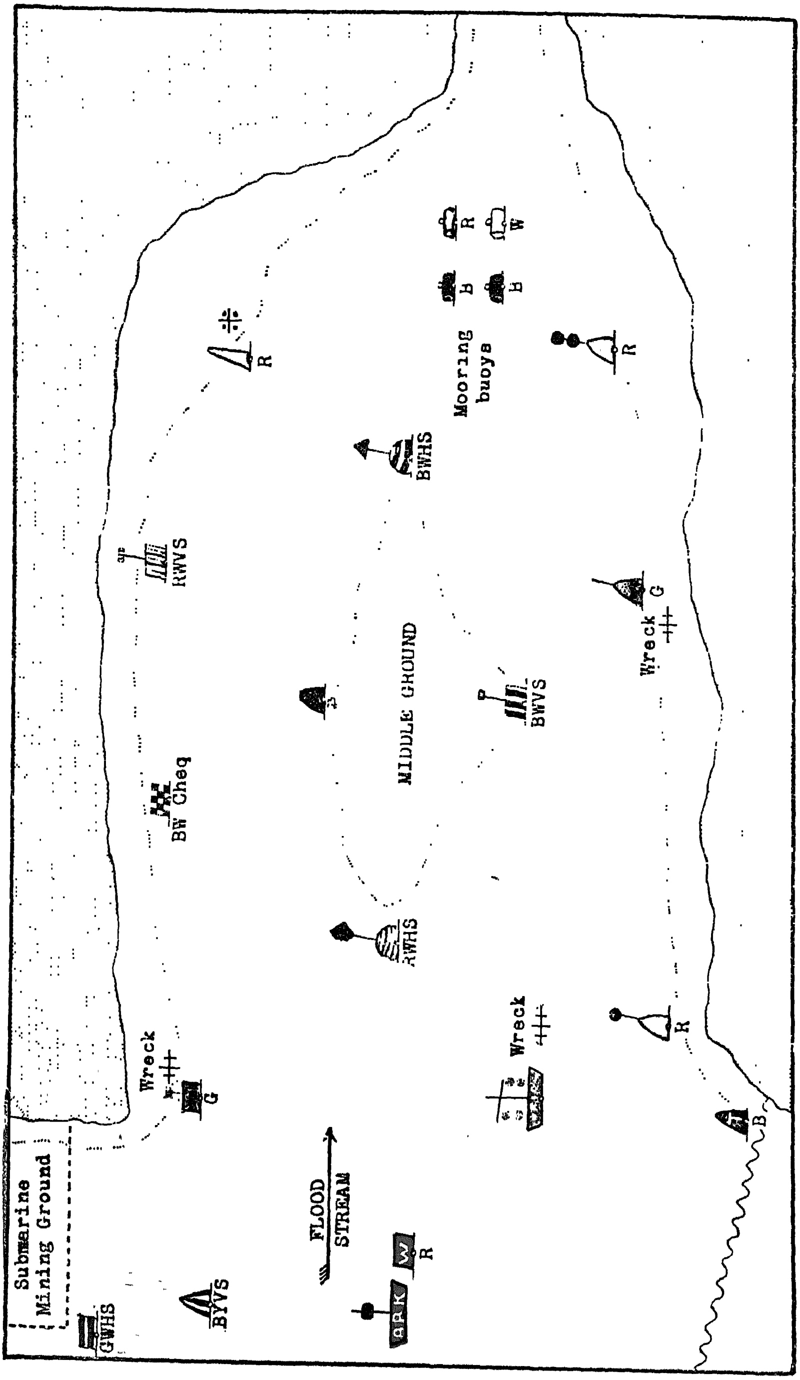

Submarine
Mining Ground
GWHS
BYVS
FLOOD
STREAM
R
Wreck
G
RWHS
Wreck
B
R
BW Cheq
MIDDLE GROUND
BWVS
Wreck
G
RWVS
BWHS
R
Mooring
buoys
R
B
B
W
R

FIGURE 69.

SYSTEM OF WRECK MARKING OFF THE COASTS OF THE BRITISH ISLES

Details of wreck-marking vessels and wreck-marking buoys are shown in figure 70.

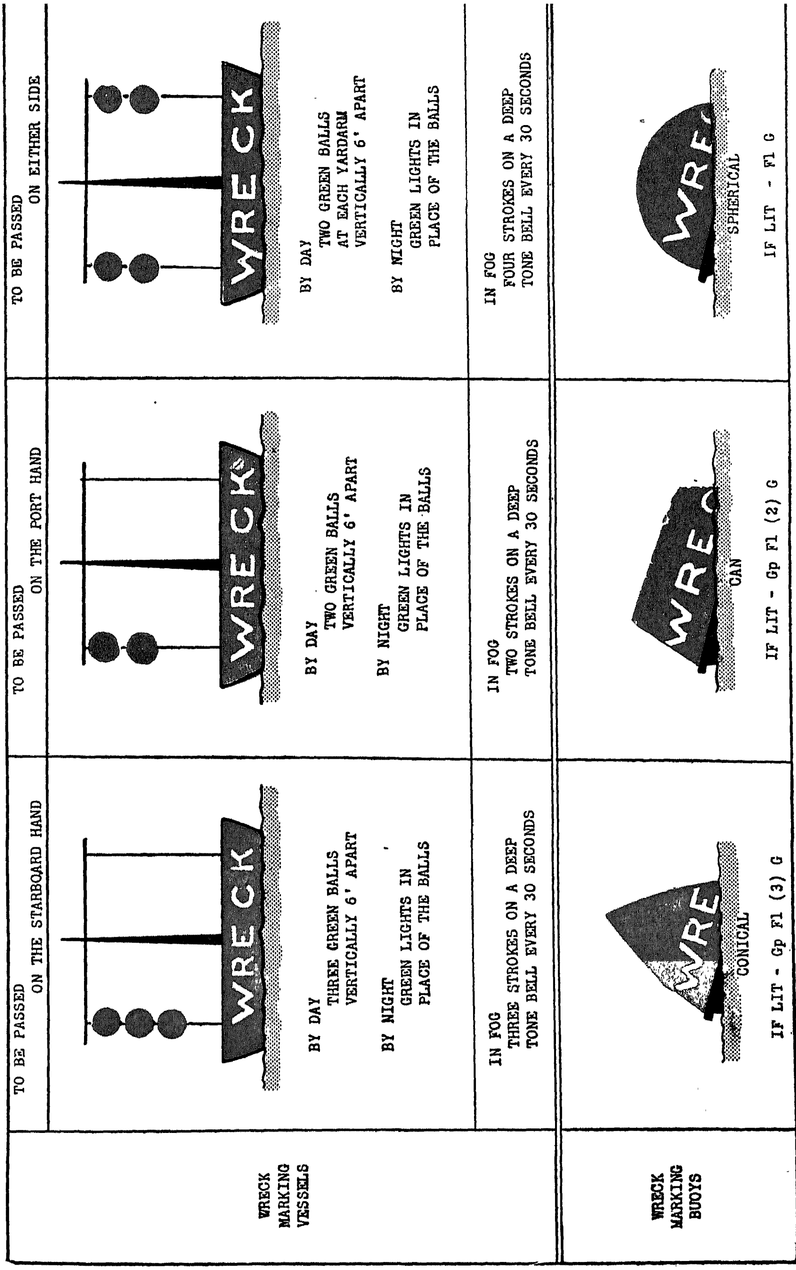


FIGURE 70.

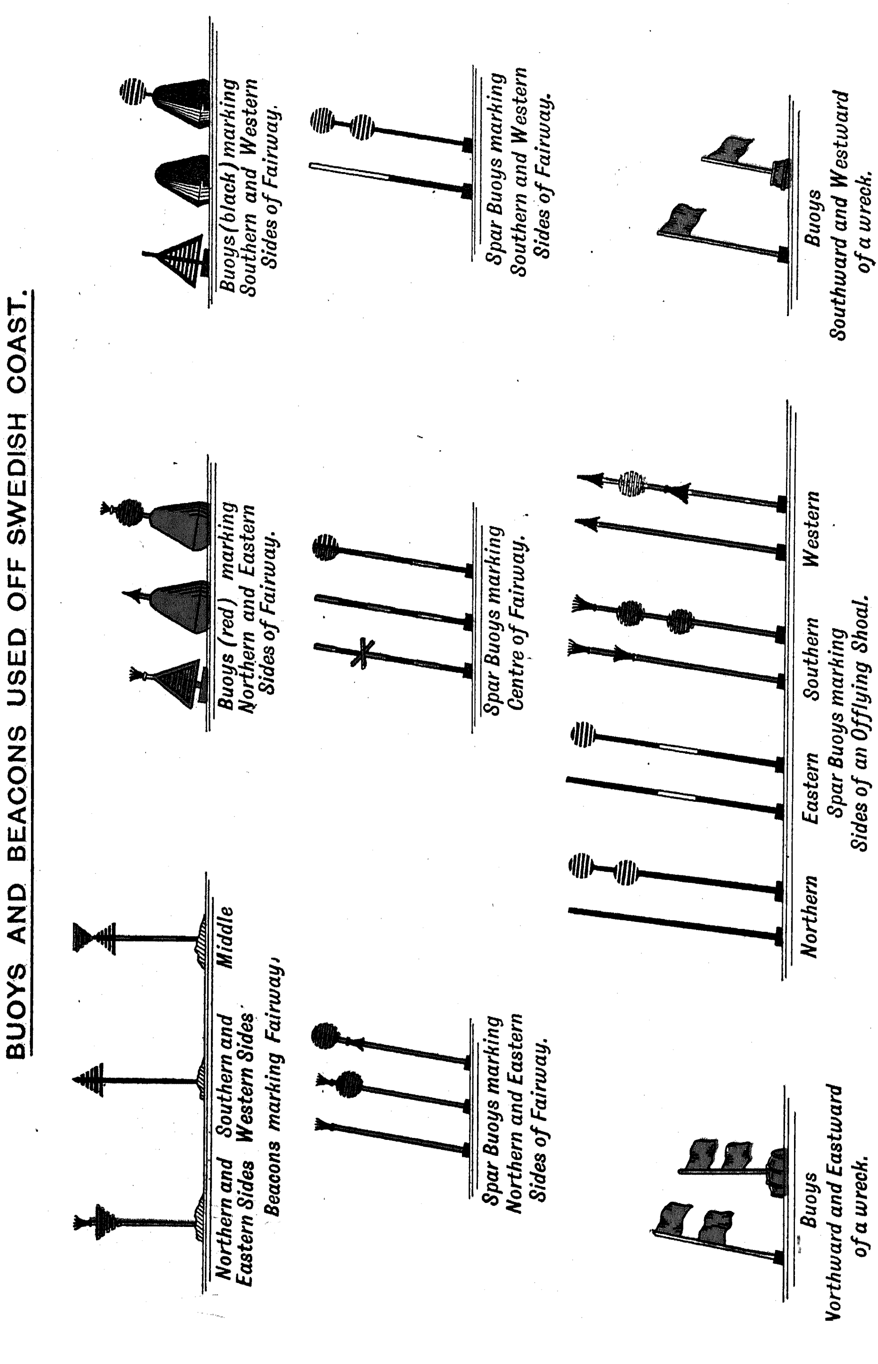

BUOYS AND BEACONS USED OFF SWEDISH COAST.
Northern and Eastern Sides
Southern and Western Sides
Middle
Beacons marking Fairway.
Buoys (red) marking Northern and Eastern Sides of Fairway.
Buoys (black) marking Southern and Western Sides of Fairway.
Spar Buoys marking Northern and Eastern Sides of Fairway.
Spar Buoys marking Centre of Fairway.
Spar Buoys marking Southern and Western Sides of Fairway.
Northern
Eastern
Southern
Western
Spar Buoys marking Sides of an Offlying Shoal.
Buoys Northward and Eastward of a wreck.
Buoys Southward and Westward of a wreck.

FIGURE 71.

FOG SIGNALS

Information concerning fog signals is given :

1. **In Full Detail** in the *Light Lists* and *Admiralty List of Wireless Signals.*
2. **In Brief Detail** in the *Sailing Directions.*
3. **In Abbreviated Form** on the charts.

Points to remember when fog signals are expected to be heard:

1. Fog signals are heard at greatly varying distances because the behaviour of a sound wave in air depends on the state of the air, and that is usually unknown.
2. At times, when an air fog signal is a combination of high and low notes, one of the notes may be inaudible.
3. Occasionally there are areas round a fog signal in which it is totally inaudible.
4. A station may not be able to see a fog which exists a short distance away, and so the fog signal will not be sounded.
5. Some fog signals take time to start up after signs of fog have been seen.

TABLE OF AIR FOG SIGNALS

Full details are given in the *Light Lists*

Fog Signal	*Operated by*	*Note*	*Remarks*
Diaphone.	Compressed air.	Powerful low note.	Distinguished by a 'grunt' at the end of the note.
Siren.	Compressed air.	Medium power high or low note or combination.	
Reed.	Compressed air.	Low power. High note.	If the reed is operated by hand, the power will be small.
Nautophone.	Electricity.	High note, similar in power and tone to the reed.	
Gun.	Gun.		An acetylene gun gives a bright flash.
Explosive.	An explosion in mid-air.		
Bell.	Mechanically or by the action of sea waves.	According to the weight of the bell.	When the bell is worked by waves the sound is irregular.
Whistle ..	Usually by wave action.	Low power and low note.	Will not operate in a calm.

W/T FOG SIGNALS AND BEACONS

Full details are given in the *Admiralty List of Wireless Signals.*

These signals are mainly designed as aids to navigation during periods of fog or low visibility, but certain stations (wireless beacons) are operated irrespective of the weather. Most fog-signal stations send out signals known as 'clear weather transmissions', at fixed times daily in clear weather. In some stations an automatic submarine sound signal is operated in conjunction with the wireless signal, to give the distance of the ship from the station, as described below.

1. **W/T Fog Signal.** Some lighthouses and light-vessels are fitted with W/T transmitting apparatus which sends out the following signals during periods of fog and low visibility :

(*a*) a morse code signal, by which the station can be identified.

(*b*) a long dash or series of dashes to enable ships fitted with direction finding apparatus to obtain a bearing of the station.

Sometimes these signals are synchronised with :

(i) a submarine fog signal (see Le Havre light-vessel) and if this is done, the time interval between the 'starting signal' by W/T and the receipt of the part of the sound signal synchronised with it, will give a measure of the distance from the station, the approximate distance in miles being the time interval in seconds multiplied by 0·8.

(ii) an air fog signal, in which event the approximate distance in miles is the time interval in seconds multiplied by 0·18.

2. **W/T Beacon.** These are stations that work independently of the weather and transmit signals at certain fixed times daily. Experimental beacons are established in various countries, and full particulars are given in the *Admiralty List of Wireless Signals.* The following are examples :

(*a*) **Rotating Loop Beacon.** An experimental rotating loop beacon has been established at Orfordness and consists of a medium wave W/T beam, rotating at uniform speed.

A continuous signal is transmitted, with special code signals as the minimum beam passes certain points of the compass. As the beam rotates, the strength rises and falls, and since the speed of rotation of the beam is known, the bearing of the station can be calculated by measuring the time interval between the passage of the beam past a known point of the compass, which is indicated by the code signal referred to, and its passage past the ship, which is indicated by the minimum strength.

These signals are received on a standard receiver.

(*b*) **Talking Beacon.** An experimental talking beacon at Little Cumbrae lighthouse consists of an ordinary mechanical fog siren and an R/T transmitter containing a gramophone record which speaks the name *Cumbrae* and calls distance in cables up to five miles. The distances are spoken on the wireless at intervals corresponding to the time taken by the sound to travel each distance. Since W/T is heard instantaneously, the listener in the ship notes which W/T spoken distance he hears at the moment the air sound signal is heard.

In addition to the above station, W/T fog beacons are established which enable the observer to obtain his bearing from the station without the use of direction-finding apparatus.

(*c*) **Directional Beam.** Another type of beacon, very little used, however, is the directional beam transmitter which sends out signals in one direction only. Other signals are transmitted, differing on either side of this beam, and ships can thus determine their course towards the beacon. A beacon of this type is at present (1938) in use at La Palmyre, France.

Notes on W/T Fog Signals

1. Remember that there may be serious danger if W/T fog signals are misused, and there may be a risk of collision with light-vessels operating such signals.

2. The vagaries of sound in fog are well known, and the navigator who, in thick weather, approaches a W/T fog signal directly ahead on a W/T bearing and relies on hearing the sound fog signal in sufficient time to alter course to avoid danger, is taking an unjustifiable risk.

W/T fog signals give no indication of distance, and safety demands that every precaution should be taken. If such signals are carried on light-vessels, risk of collision can be avoided by ensuring that the bearing does not remain constant.

3. Stations which distinguish between their fog and clear weather operation give automatic indication of the local visibility at the station. For example, if they make fog signals, it may be assumed that there is fog at the station.

SUBMARINE FOG SIGNALS

Submarine fog signals can be sent by two methods.

1. An electrically operated instrument called a submarine oscillator (chart abbreviation S.O.) which transmits a high note signal. The signal is usually a group of notes corresponding to letters in the morse code.

2. Submarine bells (chart abbreviation S.B.) frequently fitted to buoys. They may be operated either mechanically or by wave motion. In the latter type the sound is irregular and since it is usual to find a calm sea in foggy weather, it is possible that bells operated by wave motion may not be heard.

Sound. Sound in air travels at about 1,130 feet per second, but, owing to acoustic waves and fogs, aerial sound waves are variable in their progress.

In water, sound waves travel about four times as fast as in air (about 4,900 feet per second), and their progress is therefore much less variable. They spread out in all directions, but are apparently diverted or deflected by shoals, land, breakwaters and, possibly, by strong tides.

The range of submarine signals far exceeds that of air fog signals. Submarine oscillators (S.O.) have been heard at distances exceeding 25 miles and submarine bells (S.B.) at distances exceeding 15 miles.

Hydrophones. Ships fitted with receiving gear can find the bearing of a submarine fog signal with sufficient accuracy for safe navigation in a fog. Ships not so fitted can hear the signals from the hull below the waterline for distances which are well outside the normal range of air fog signals, though it is difficult to obtain an accurate bearing.

H.M. ships are not fitted with receiving gear.

CHAPTER VIII

NAVIGATIONAL INSTRUMENTS

The following navigational instruments form the subject of separate books or chapters:

The Sextant and Bubble Sextant	Appendix I and Volume II.
The Star Globe	Appendix II.
Chronometers and Watches ..	Chapter XI.
Compasses:	
Gyro	Chapter IX and the *Admiralty Manual of the Sperry Gyro Compass.*
Magnetic	Chapter X.
Meteorological Instruments ..	Chapter XIII and the *Weather Manual.*

Other instruments are divided into separate groups as follows:

To find the ship's speed and distance run

1. The Pitometer log.
2. The Chernikeef log.
3. Walker's logs.
4. The Dutchman's log.
5. Speed by engine revolutions.

To find the depth of water

1. Echo sounding.
2. Kelvin's sounding machine.

Rangefinders and distance meters

1. The navigational rangefinder.
2. The Weymouth Cooke sextant rangefinder.
3. Stuart's distance meter.

Course-recording instruments

1. The Brewerton course recorder.
2. Plotting instrument. Mark V.
3. The Battenberg course indicator.

Plotting instruments

1. The station pointer.
2. The Douglas protractor.

THE PITOMETER LOG

Full details of this log are given in the handbook supplied with each log.

The Pitometer is a pressure-type log. A *pitot* tube A projects about 3 feet through a sluice valve H in the bottom of the ship. This length varies with different classes of ships. In the end of the pitot tube there are two orifices which take the impact and static pressure. These are connected to two tubes BB′ and CC′, running lengthwise up the rod. The tops of these tubes are connected by pipes to a mercury differential consisting of a float chamber D which

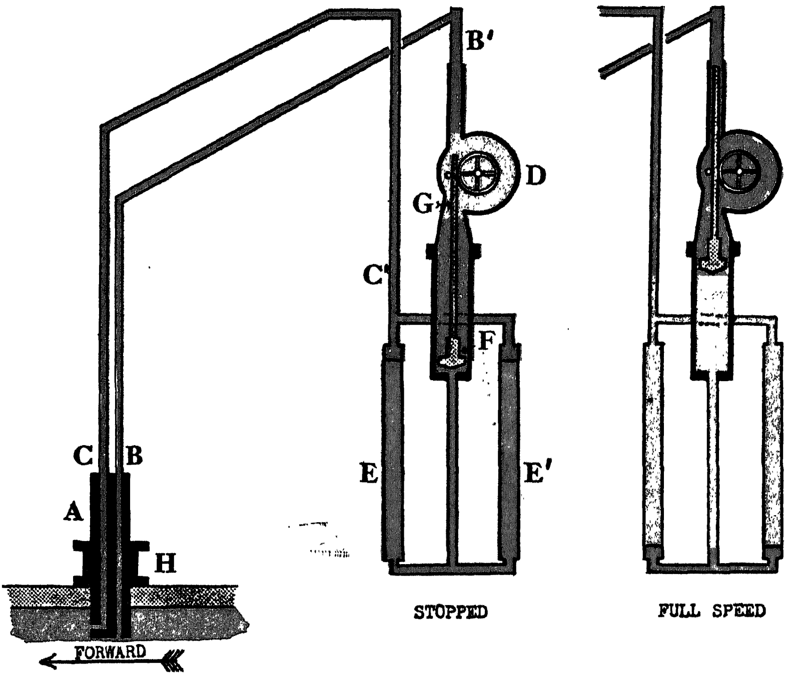


FIGURE 72.

communicates with two large tubes, E and E′, one on each side, the whole being mounted in gimbals.

The float chamber and tubes are filled with mercury to a certain level. Above the mercury, the differential is filled with water and all air is expelled.

The impact pipe leads to the outside tubes, and the static pipe to the float chamber.

When the ship is stopped, the mercury is at the same level in the tubes and in the float chamber, but when the ship goes ahead, the difference between impact and static pressure causes the mercury to drop in the side tubes and to rise in the float chamber.

On the mercury rests a weighted float F carrying a bronze rack G which, through a train of gear wheels, operates the master scale of the speed transmitter. *The log thus primarily measures speed.*

To measure distance, there is a unit consisting of a roller operating on a disc run by a constant speed motor. This system gives an infinitely variable gear, and distance is registered electrically in steps of one hundredth of a mile.

Calibration. Waves made by the movement of the ship cause a flow of water round the hull and this flow varies at different speeds. By calibrating each class of ship by runs on a measured mile in deep water, the effect of this flow can be found and adjustments made in the log mechanism by the Pitometer Log Company so that the log reads correctly at all speeds.

Possible Faults

1. *Clogging of the orifices* is shown by an unnatural steadiness of the master scale on the speed transmitter.

2. *Failure of the speed transmitter* is shown by a difference in the readings of the master and the setting scales.

3. *Failure of the distance transmitter* is revealed when the 'distance registers' cease to function.

The accuracy of the distance transmitter should frequently be checked by noting the average speed over a period as shown on the speed indicator, and comparing it with the distance run as shown by the distance register. Particulars of this adjustment are given in the handbook.

Advantages

1. There are no moving parts external to the ship liable to be fouled by sea-weed, waste, etc.

2. A direct indication of the speed is obtained.

Disadvantages

1. The registration of distance is not obtained directly but is dependent on the satisfactory working of an integrating mechanism.

2. The higher the speed the greater must be the size of the mercury reservoir, and the size becomes prohibitive in small fast ships.

THE CHERNIKEEF LOG

Full details of this log are given in the handbook supplied with each log.

The log consists of an impeller which can be raised and lowered so that in its running position it protrudes 15 to 18 inches below the bottom of the ship, as shown in figure 73. The impeller, when lowered, is rotated by the motion of the ship through the water, and this rotation is transmitted electrically to the distance recorder by making and breaking contacts.

The Impeller Mechanism. The impeller and gear wheel lie in a small submerged chamber at the end of a hollow vertical shaft.

This shaft contains the electrical wires, and is led up into the ship through a watertight joint. The submerged mechanism is filled with oil and made watertight.

Friction is reduced to a minimum, and it is possible to measure accurately speeds as low as half a knot.

Transmission. The only work the impeller has to do is to make and break contacts in the submerged chamber, thus transmitting electrically to the distance recorder. It actually gives 400 impulses per mile, one impulse being equivalent to a distance run through the water of 15·2 feet. Thus the Chernikeef log, as opposed to the Pitometer log, primarily measures distance, and other mechanism, introducing the time element, works out the speed.

The Distance Recorder. This may be either of the ordinary Walker-log type or of the cyclometer pattern.

Flash Lamp. The distance recorder also works a blue flash lamp from which the speed can be found by timing a definite number of flashes. Each flash records a distance run of 15·2 feet. There is a table given on the switch box containing the flash lamp (shown in figure 74) which converts time for 21 flashes (in seconds) into knots.

The Speed Indicator. The speed indicator works out the speed every 18 seconds, and thus for any alteration of speed the pointer showing knots flicks up or down to the new speed at intervals of 18 seconds.

Adjustments. The only method of correcting an error in this log is by bending the blades with a special tool and so altering the pitch of the impeller.

Full instructions for making this adjustment are given in the handbook, but it should be noted that greater accuracy will result if the blades are first bent slightly beyond the required percentage correction.

Possible Faults

1. The log may stop because the impeller is foul.
2. Readings may be unsatisfactory because the contacts in the submerged mechanism or in the cables and various components of the speed indicator are faulty.

Advantage of the Log

1. The log makes it possible to measure very low speeds such as that of a current when the ship is at anchor.
2. Adjustment is possible by bending the impeller blades.

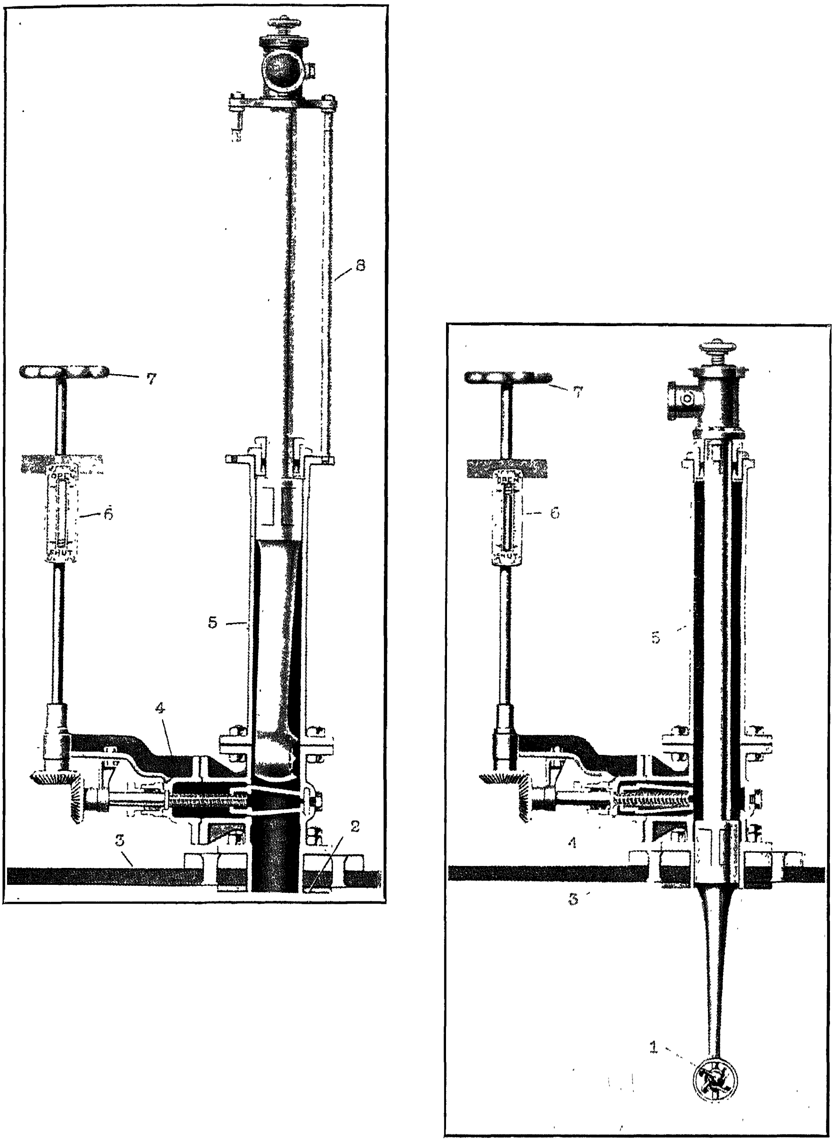
Disadvantage. The impeller is delicate and can easily be obstructed and perhaps damaged by sea-weed, etc.

WALKER'S LOGS

These logs are of the towed type. The principle is that a small screw-propeller, called the *rotator*, when towed through the water,

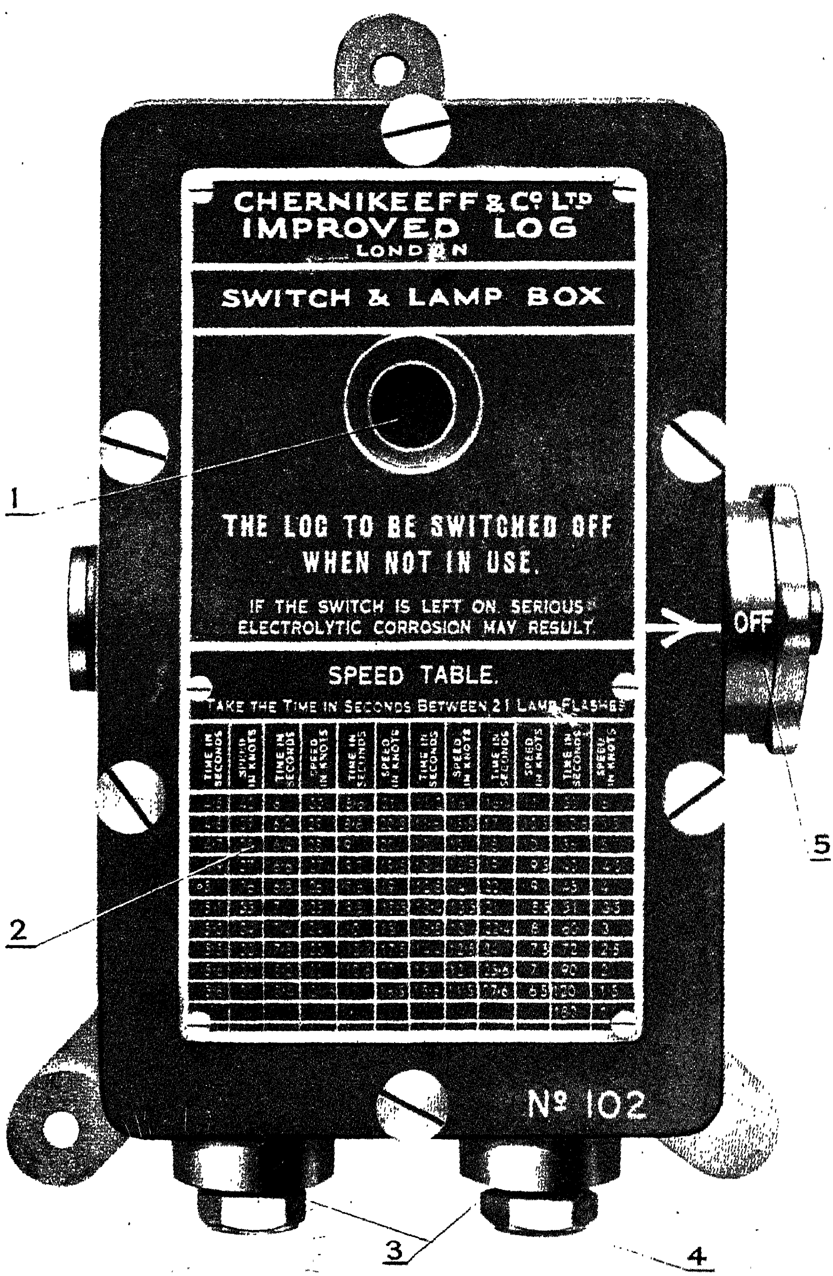
[*To face p.* 180.

Log drawn in **Log in working position**



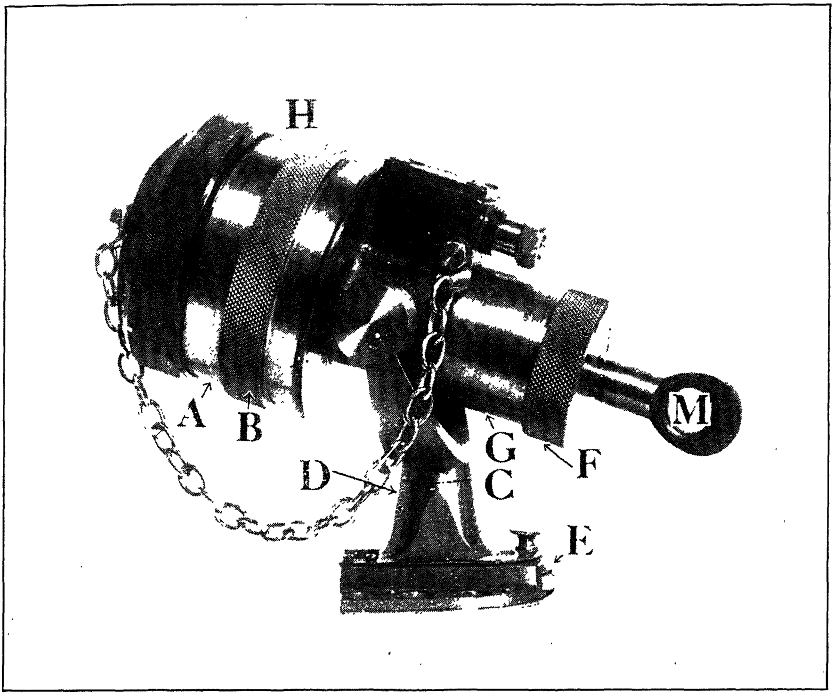
1. Impeller.
2. Zinc protection ring.
3. Hull plate.
4. Sluice valve.
5. Log housing.
6. Valve indicator.
7. Valve operating wheel.
8. Check tube in position.

FIGURE 73.



1. Flash lamp.
2. Speed table.
3. Cable gland nuts.
4. Gland washer.
5. Operating handle.

FIGURE 74



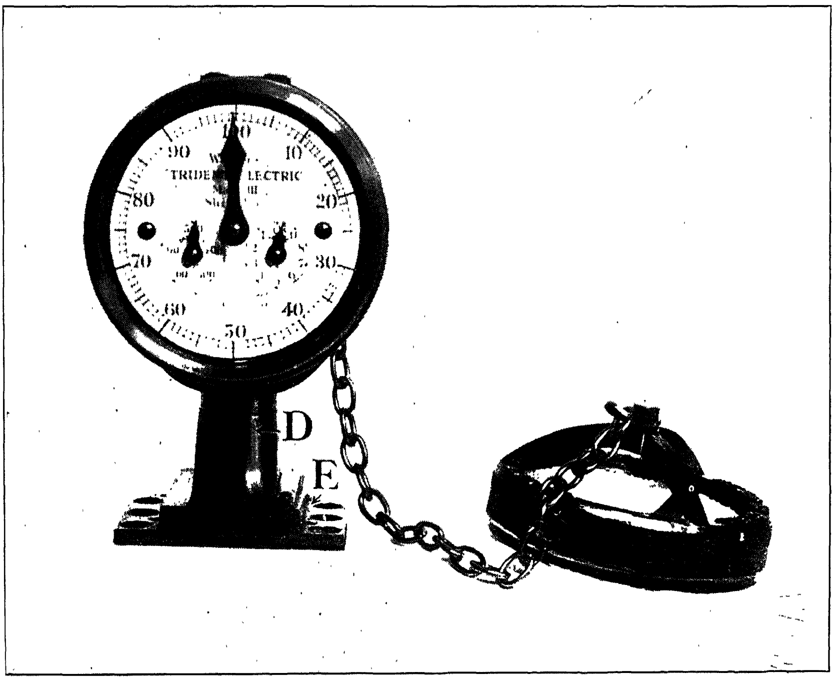


FIGURE 75.

apparatus, and a receiver. The dial of the receiver is arranged in a similar way to that of the registering apparatus, as shown in figure 75. The receiver itself is in the chart-house and is connected by a permanent circuit to terminals at the stern of the ship. A watertight flexible lead from the terminals is connected to the registering apparatus at the watertight connection H. The make-and-break mechanism completes the circuit at every tenth of a mile as indicated by the instrument, and thus every movement of the handle of the registering apparatus is repeated on the receiver. It is important to see that the log circuit is switched off when the log is not in use.

Handling the Rotator. Take care when handling the rotator that the blades are not damaged, for a blow may impair the accuracy of the instrument. When the log is to be used, the governor wheel should be attached to the registering apparatus by the eye M and the rotator put overboard, the hook on the inner end of the line being placed in the eye of the governor. Set the hands to zero, working them anti-clockwise.

Hauling in After Use. To haul in the log after use, haul in some of the line abaft the governor and pay out the hook end over the stern on the opposite side of the ship, while hauling in the rotator. When the rotator is inboard, the line can be hauled on board again and will be free of turns.

It is most important to haul in the log before the ship goes astern. Unless this is done, the rotator will be lost.

Supply of Log lines. The log line is a specially made line, supplied in lengths of 65 fathoms. The accuracy of the log depends largely on using the correct length of line, and the following lengths have been found suitable for normal vessels :

For a maximum speed of 10 knots : 40 fathoms
15 knots : 50–55 fathoms
18 knots and over : 65–70 fathoms

Lengthening the line usually increases the registration, and *vice versa.*

It is better to use a line too long than too short, because it keeps the rotator deeper in the water.

The Error of a Patent Log. Take every opportunity to check the patent log and record in the *Navigational Data Book* any errors found. These errors are always expressed as a percentage of the *distance logged* and not of the distance run.

The logs may be checked in two ways, the second of which is preferable because it is more accurate :

1. From a run between two points at a known distance apart, due allowance being made for the tidal stream or current.

2. From runs over a measured distance, with and against the tidal stream.

Disadvantages ·

1. The rotator is liable to become choked with seaweed or cotton waste, or damaged by floating timber.
2. The ship cannot go astern without hauling in the rotator.
3. It is inaccurate in a heavy following sea.

THE DUTCHMAN'S LOG

This is an accurate method of finding the speed of the ship at a given moment, when out of sight of land. It can be used advantageously during power trials in the open sea.

Before the trial select two observation stations on the upper deck, one forward and one aft. The horizontal distance between the stations, which must be accurately measured from the plan of the ship, should be as great as possible. At each station a fixed open sight should be set up and trained accurately on the beam. If possible, each station should be connected by buzzer to a control position. Numerous floats of suitable shape and size should be prepared, and if possible a catapult should be constructed for throwing the floats from the forecastle. The forward observation station must be sufficiently far aft to allow the floats to reach the water before they pass the line of sight. If arrangements can be made for other ships to drop the floats from a position ahead, so that the floats will pass the observing ship at about three-quarters of a cable on the beam, the observation stations can be nearly the whole length of the ship apart.

When all is ready, a float is dropped from the ship ahead, or catapulted from right forward as far as possible on the bow. At the moment the float passes the line of sight, the observer at each station presses his buzzer key and both times are noted to 1/5 second at the control position. About five floats, dropped at short intervals, are required for each set of observations ; and the mean of the speeds obtained from the five observations should be taken to be the speed of the ship during the period covered by the observations. Great accuracy in observing and taking times is necessary to obtain correct results in a fast ship ; for example, if the observers are 167 yards apart and the speed of the ship is 30 knots, an error of 1/5 second in the elapsed time will produce an error of 0·6 knot in the speed obtained from one observation.

TO FIND THE SHIP'S SPEED BY ENGINE REVOLUTIONS

A table, known as the *Table of Revolutions*, is made out for each ship from actual trials and entered in the *Navigational Data Book*. It gives the revolutions per minute of the engines required for each knot of the ship's speed in smooth water, when the draught is normal and the bottom clean. This table is a good guide for estimating the speed through the water if due allowances are made for varia-

tions in draught, the state of the ship's bottom, and the effect of wind and sea. As a rule it is easier to estimate these allowances for a large ship than for a small one.

NOTES ON PATENT LOGS

There is a tendency for all bottom logs to overlog at high speeds and to underlog as the bottom becomes foul.

The latest trials show that the range of these errors on either count is not likely to exceed 5 per cent.

The errors are almost certainly due to varying stream-line effects in the vicinity of the log at different speeds and according to the state of the ship's bottom.

If the log is not fitted at the exact turning point of the ship there will be a small error when the ship alters course, but its effect will be appreciable only if there are frequent large alterations of course, mostly in the same direction.

From the foregoing facts it is seen that a close watch should be kept on the bottom log, and curves should be obtained showing the percentage error for various speeds and various states of the ship's bottom. These data should be entered in the *Navigational Data Book* and should be constantly checked.

A towed log is unaffected by bottom conditions and affords a valuable check on the behaviour of bottom logs at speeds up to 20 to 25 knots in varying seas. The error when course is altered is not appreciable because, although the stern of the ship describes a larger circle than the pivoting point, the actual rotator follows on a smaller circle which is probably not very different from that of the pivoting point.

Take, therefore, every opportunity to make use of the Walker log as a check, especially during long passages.

ECHO SOUNDING

The development in the last few years of echo sounding has given the navigator a means of measuring the depth of water under his ship far superior to any that he has previously used, because it enables him to obtain the sounding under a ship without the use of any form of lead and measuring line or mechanical sounding machine.

Echo sounding instruments have been developed with great rapidity. There are at present two main types.

1. Sonic-type listening gear.
2. Supersonic automatic recording gear.

NOTE. Sonic type of echo sounding gear incorporating a recorder is now under trial (1937) and if successful the recorder will supersede the listening gear mentioned in (1) above.

SONIC-TYPE LISTENING GEAR

In measuring the depth of water by echo methods, a ship sends out an underwater sound impulse which travels outward through

the sea at a uniform speed. On reaching the ocean bed, part of the sound is reflected and returns as an echo to the ship, where its arrival is heard by listening on telephones.

The velocity of the sound in its passage to and from the ocean bed is known, and so by measuring the time interval between making the sound and hearing the echo return, an observer in the ship can determine the depth of water.

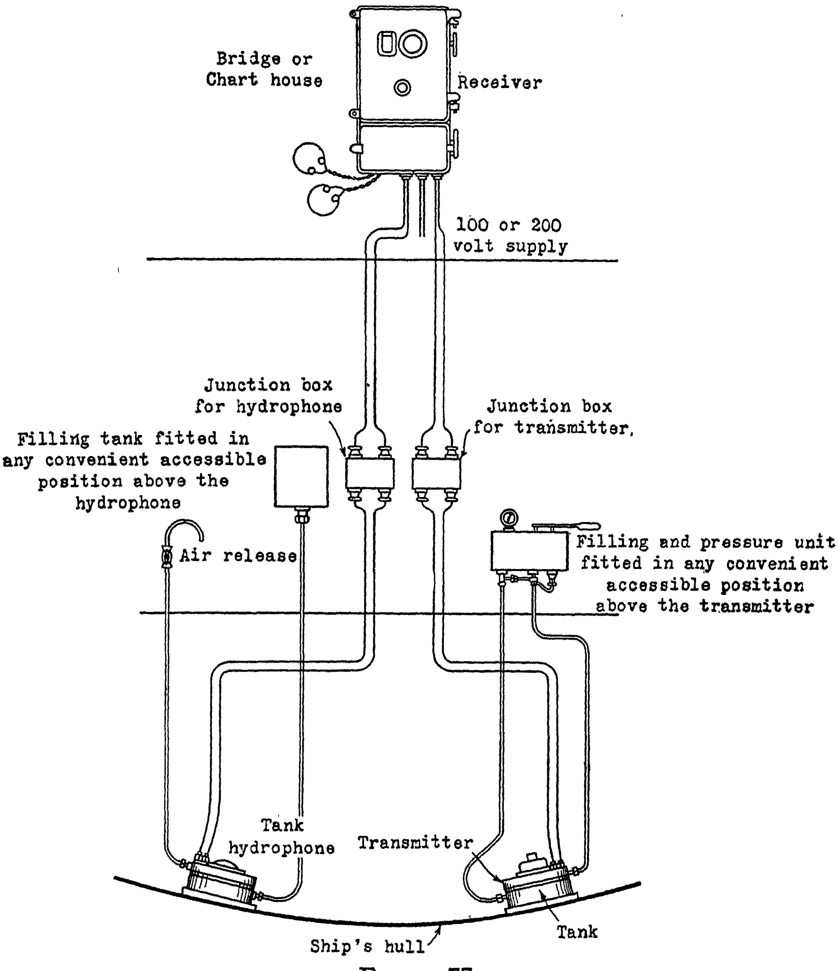


FIGURE 77.

In shallow water, this time interval is extremely short. For example, the time taken for a sound impulse to travel to a depth of 10 fathoms, to be reflected, and to return to the ship, is about one-fortieth of a second.

It is not possible to measure so short an interval by direct methods such as by use of a stop watch. Special apparatus is

provided therefore. By means of a suitably graduated scale, the interval measured is converted into fathoms, and the operator is able to find the depth of water direct from the instrument.

Echo Sounding Type 752 (Sonic Type). This type is fitted in most of H.M. ships and measures depths from 3 to 140 fathoms. (For full details, see B.R. 309.)

Principal Parts. The *transmitter* produces a sound impulse by a blow from a spring-driven electrically-operated hammer on a steel diaphragm in a tank secured to the ship's hull. The sound impulse is transmitted through the water to the hull of the ship, which acts as a diaphragm and re-transmits the impulse to the sea outside the hull.

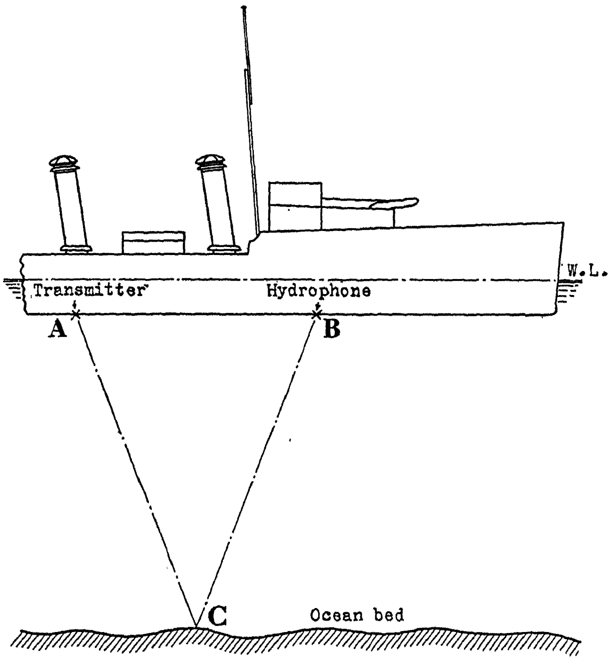


FIGURE 78.

The electro magnet which operates the hammer is controlled by an automatic switch inside the receiver and is regulated so that the hammer delivers three blows per second to the diaphragm.

The *hydrophone* consists of a microphone and diaphragm mounted in another tank, and it picks up the echo from the ocean bed. The hydrophone is placed at a suitable distance from the transmitter, and on the opposite side of the keel to screen it from sound travelling direct from the transmitter. The distance between the instruments, AB in figure 78, is called the *separation*.

In type 752, allowance for separation is made in the graduation of the scale, but in earlier types the allowance is made by a special

cam influencing the movement of the time-measuring device at shallow depths.

The *receiver* makes the echo audible to the operator and contains the time-measuring device and a graduated scale for reading off the depth. It also contains the switches for operating the transmitter and hydrophone.

The sound reflected from the sea bed agitates the hydrophone which is connected to telephone receivers, but the leads are short-circuited except when one of the rotating telephone brushes is on the insulated segment of the *telephone shorting disc* (T.S.D.). The T.S.D. may be rotated by the handwheel, and the position of the insulated segment thus altered relative to the rotating telephone brushes at the instant when a transmission is made.

For an echo to be received from zero depth below the ship the T.S.D. must theoretically be turned until the rotating telephone brush passes over the insulated segment at the same instant as transmissions are made, and for this position the scale (which is secured to the periphery of the T.S.D.) should read accordingly.

When the insulated segment on the T.S.D. is moved so that an echo at some other depth is audible, the time taken for the sound to travel to the bottom and back is equal to the time required for the telephone brush to traverse the arc through which the segment has been turned.

Therefore, if the brushes revolve at a constant known speed, the amount of movement of the segment (and the T.S.D.) is a measure of the depth, and the scale which is attached to the T.S.D., enables this movement to be read off directly as a depth.

Due allowance is made in the calibration of the scale for separation and the draught of the ship, so that the depth recorded is the *actual* depth and *not* the depth below ship.

To Operate the Gear. Make the control switch. Turn the operating handle until the scale pointer is in line with the lowest reading on the depth scale. Plug in and put on the headphones. Three taps per second will be heard continuously whatever the position of the scale. These taps are due to interference noises in the hydrophone each time the telephones are open-circuited, and are not necessarily echoes from the bottom.

Turn the operating handle so that the depth scale reading is slowly increased. When the correct depth is reached, the tapping noise will suddenly increase in volume, and the note will be clear-cut.

The correct depth is indicated by the scale reading when the alteration of sound first occurs.

On turning the scale further, echoes will continue to be heard (probably louder) but these should be neglected.

To Maintain Soundings. After obtaining the first sounding, turn the scale back until echoes cease to be heard, and continue

turning back for about two fathoms below this point. Then turn the scale up again until echoes are regained, continuing this procedure as long as the soundings are required. The correct sounding is the depth shown each time the sound first intensifies when the scale readings are being increased.

The loudness of the echoes can be altered by means of an adjustable resistance on the front of the receiver.

When the echoes are very loud, it is often advisable to decrease the hydrophone sensitivity in order to rest the operator's ears. Continuous operating with loud echoes is very uncomfortable for the average operator. The best sensitivity to use varies with different persons, but, after a little experience, an operator should be able to decide whether he finds it more satisfactory to work with a high or low sensitivity.

To Obtain a Sounding when Approaching the Land from Deep Water. It must be remembered in these circumstances that when the 100 fathom line, say, is to be picked up, it is not correct to adjust the depth scale at this setting, and run in until the alteration of tone is heard in the headphones, because the principle involved in this method is wrong. The correct depth is recorded on the scale when the alteration of tone is heard from a shallower to a deeper sounding. The scale must, therefore, be continuously turned up to 100 fathoms until an echo is obtained at this depth.

NOTES ON OPERATING

Sometimes a false echo may be picked up in the headphones, but with experience, the true echo and the false echo can invariably be distinguished by a different quality in the note heard.

A muddy bottom will not give such a good echo as a hard sand or rocky bottom.

Owing to the frequency with which soundings are taken, it will sometimes be found that variations of the depth occur within two or three feet either side of an average depth.

This occurs because the echo sounding gear searches out all unevenness of the bottom. If the gear is worked correctly over anything but an abnormally irregular sea bed, the echo sounding receiver will show the depth of the sea immediately under a position midway between the position of the transmitter and the receiver.

Corrections. Corrections for temperature, salinity and pressure can be made from H.D. 282 : *Velocity of sound in pure and sea water.* These corrections are unnecessary in ordinary circumstances.

Adjustment and Maintenance. Full details are given in the hand-books supplied with the various sets.

Defects and their Remedies

1 *Faint echo* may be caused by :

(*a*) the spring being too long, thus allowing no clearance between the hammer and the anvil.

[To face p. 188.

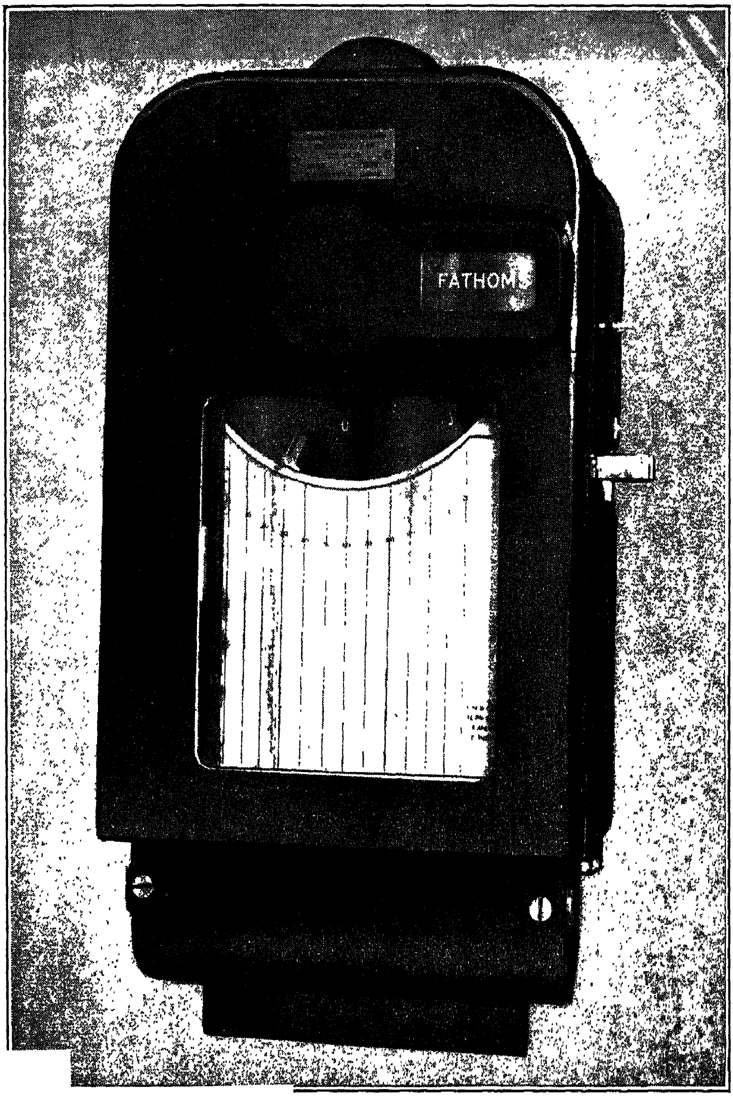
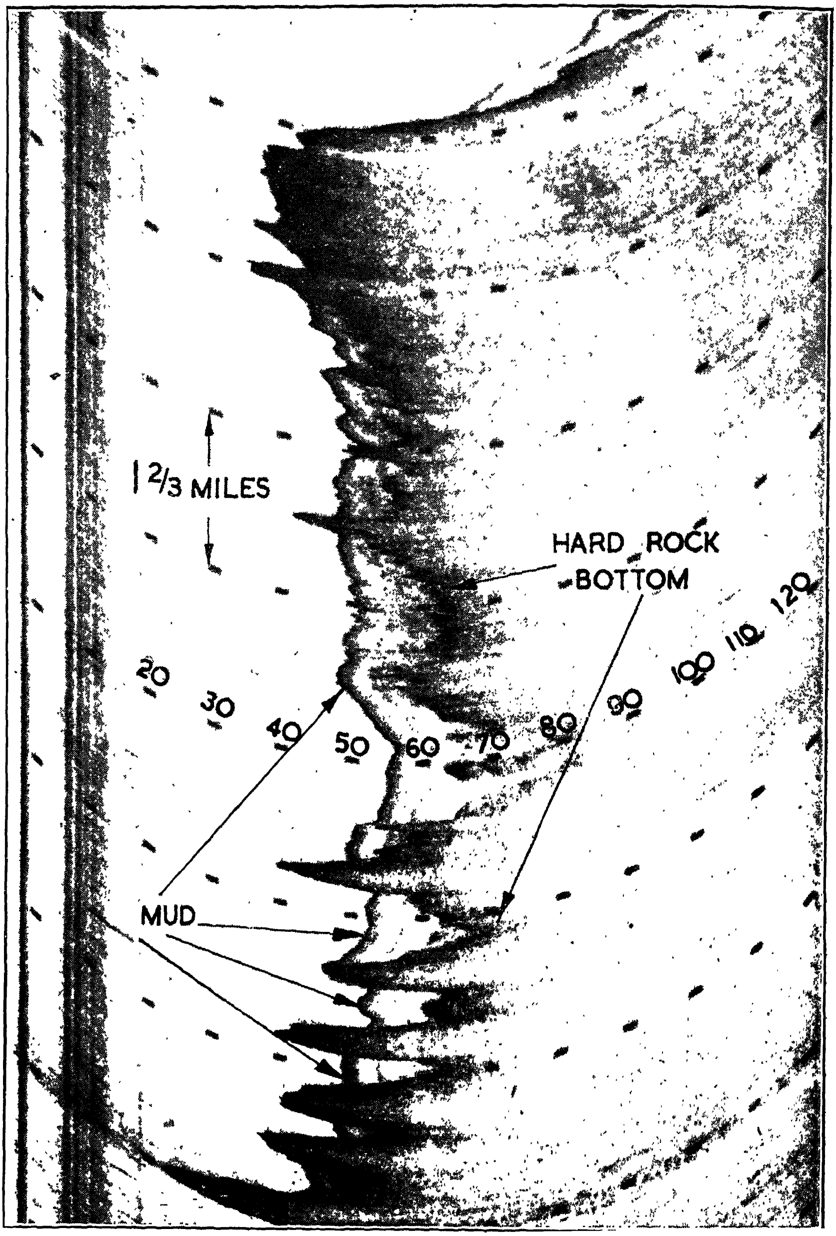


FIGURE 79.



Photograph of record obtained from Type 753 Recorder in H.M.S. *Mohawk* during trials in the River Clyde. Speed 20 knots. Soundings in fathoms.

FIGURE 80.

(*b*) the spring being too short, thus making the distance between the hammer and the anvil too great.
(*c*) faulty transmitter coils.
(*d*) a fault in the hydrophone circuit.

2. *Roaring in the headphones.* This happens when the brushes on the telephone disc do not make proper contact.

3. *Crackling in the headphones.* This happens when the microphone button is loose in the wing adaptor, or when the microphone button is insufficiently packed with carbon granules.

4. *No hammering* occurs if the spring breaks.

5. *Obviously incorrect or 'variable' soundings.* These result from lack of pressure in the transmitter tank. To avoid them it is advisable to check the setting of zero on the scale with the transmitter break.

To Use the Hydrophone by Itself. Turn the switch to the first position and put the telephone brushes on the insulated segment. This is useful for finding the ship's position by radio sound ranging, as described in Volume III, and for listening to submarine bells, etc.

Echo Sounding Types 753 and 754. These types are superseding type 752. The same designs of transmitter and hydrophone are used in them, but the receiver is replaced by a recorder, an example of which is shown in figure 79. This recorder unit contains all the control elements of the equipment, and consists of a constant-speed motor driving rotary switches in step with a recording stylus.

The speed of travel of the stylus is proportional to the speed of sound in water. A strip of damp sensitised paper passes slowly beneath the rotating stylus. The echo generates a small current in the receiver, and when this current is amplified and passed through the stylus and paper, it liberates iodine and makes a sharply defined sepia stain.

The depth can be read from a scale fitted over the front of the paper.

Every five minutes the stylus is actuated by a special switch and commutator and makes a series of marks across the paper at ten-fathom intervals.

A "fix marker", operated by a push button, draws a line across the paper at any desired times. This is effected by completing a circuit from a small battery through the stylus and paper.

An electric pencil, energised by the same battery, can be used for writing times, etc., on the record.

All types of recorders give some idea of the nature of the bottom. Rock, for example, produces a sharply-defined line, and mud over rock a double line not so sharply defined. Figure 80 reproduces a record made by this gear.

THE MAGNETO-STRICTION ECHO SOUNDING SET

This was devised, orginally, for surveying motor boats with a range of 0 to 360 feet, a range which can be increased, by altering the

speed of stylus and paper, to 360 fathoms. The success of this type has led to its installation, with various modifications, in merchant ships, and it will be fitted in all H.M. ships to replace types 752, 753 and 754.

The System. A supersonic signal is produced (and the echo received) by high-frequency magneto-striction oscillators. The echo generates in the receiver high-frequency currents which are amplified and passed through a chemical recorder. The motor driving the recorder also controls the instant of transmission of the signal so that the movement of the recording stylus is synchronised with the regular sequence of signals. While the oscillation travels to the sea bed and back, the recording stylus traverses a proportionate distance over the chemically-prepared paper.

The stylus and the recording drum being in the circuit, a stain is recorded on the paper each time current passes ; that is, at the moments of transmission and receipt of the echo. Hence two lines are traced on the recording paper, one representing zero and the other the depth.

Advantages

1. It is inaudible except to receiving apparatus tuned to its own frequency.
2. It is directional.
3. It gives instant indication of the depth.
4. Being supersonic, it is less liable to interference from extraneous noises.
5. There is no separation error and the transmitter and receiver can be fitted in the same compartment.

Ranges of Recorders

Recorder Universal A/S 45 (Oceanic Survey)	0–600 fathoms. 0–6,000 fathoms.
Recorder Universal A/S 46 (Shallow Water)	0–600 feet. 0–600 fathoms.
Recorder Universal A/S 47 (Boat)	0–360 feet. 0–360 fathoms.
Recorder Universal A/S 48 (Navigational Type 753)	0–125 fathoms.
Recorder Universal A/S 49 (3,000 fathoms)	0–300 fathoms. 0–3,000 fathoms.
Recorder Universal A/S 50 (Navigational Type 754)	0–30 fathoms. 0–300 fathoms.

KELVIN'S SOUNDING MACHINE

There are two types of Mark IV machines. One is worked by hand and the other by an electric motor.

In the motor machine, a metal frame, bolted to the deck with

the motor switch casing outboard, supports a horizontal spindle in two bearings. The following parts are mounted on this spindle.

1. A beechwood cheek, keyed to the spindle, and known as the left brake cheek (seen from inboard).

2. The wire drum, with a ' lignum vitæ ' bush, free on the spindle. On the side of the wire drum is a projection, which fits in a fork connected to the worm and worm wheel of the counter gear. Also on the side of the drum is a ' V ' groove round which passes the automatic brake cord. Between the drum and the left brake cheek

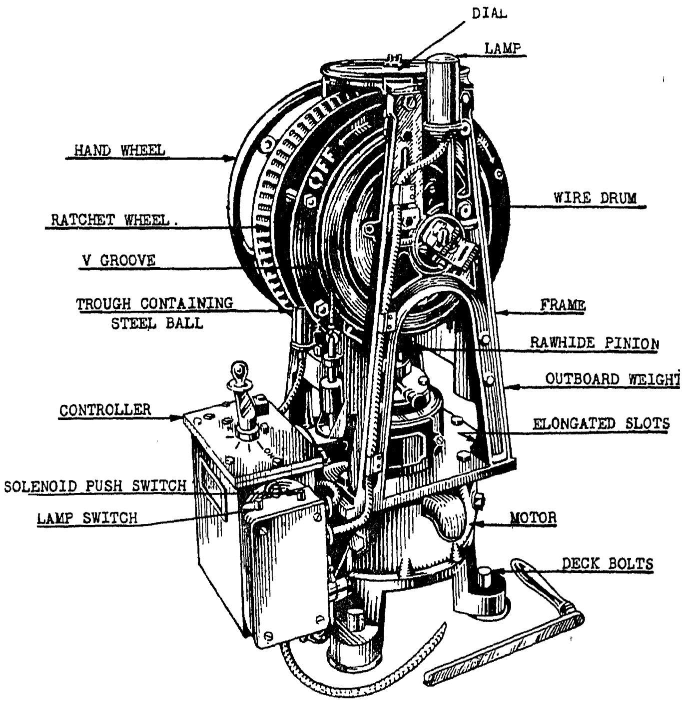


FIGURE 81.

is a spring, called the ' saucer-shaped spring ', which is in compression when the brake is on. The drum has 300 fathoms of special seven-stranded wire, the inboard end of which is secured through two small holes in the drum and back round its own part.

3. A beechwood cheek, known as the right brake cheek.

4. A ratchet wheel which is fixed to the right brake cheek. Both move on a part of the spindle which is threaded and allows them to travel towards or away from the drum. The ratchet wheel engages a hardened steel ball, lying free in a small trough fixed to the front strut casing of the framework. The bottom of this trough is an inclined plane, lying tangential to the ratchet wheel and

arranged so that the ball cannot escape. When free, the ball rolls to the bottom of the inclined plane, engages the ratchet wheel, and prevents it from turning in an outboard direction.

5. A gear wheel keyed to the spindle and engaging a raw-hide pinion on the armature shaft of the motor. When the motor revolves, the spindle is turned by this gearing.

6. A hand wheel, keyed to the spindle.

To Take the Brake Off. Give the hand wheel *half a turn outboard.* The ratchet wheel is prevented from turning by the steel ball. When the spindle is turned, the ratchet wheel and the right brake cheek therefore move on the screw thread away from the drum. The saucer-shaped spring between the drum and the left brake cheek pushes the drum to the right, and the drum is free to revolve.

NOTE. A hand machine requires one *full turn outboard.*

To Put the Brake On. Give the hand wheel *half a turn inboard.* The slight friction due to the drum being pushed lightly by the spring against the right brake cheek, together with the inertia of the moving brake cheek and the ratchet wheel when the drum is revolving, provide sufficient resistance to keep the ratchet wheel stationary. When the spindle is turned, the right brake cheek and ratchet wheel therefore move along the screw thread towards the drum, thus putting the brake on.

Connexions Between the Wire and Lead. The wire is connected to a nine-foot hemp stray line by a swivel. The brass guard tube is seized to the stray line so that the bottom of the tube is three feet above the shank of the sinker. The stray line is secured to a 24 lb. sinker.

The Traveller may be used on either side of the ship, by shipping it the reverse way on the boom. The concave side of the carrier bracket arms should face forward on the starboard side and face aft on the port side. It is lubricated by an oil cup.

The Automatic Brake. The cord over the 'V' groove on the wire drum is connected to two weights. The inboard weight is 6 lb. and can be increased by further 1 lb. weights to allow for increased speeds of the ship. The outboard weight is 1 lb., and to obtain the correct tension on the brake it must be set up so that it is 1½ inches off its seat.

The automatic brake prevents the drum from over-running and allows the wire to run out at a constant speed for varying speeds of the ship. This is essential if a satisfactory result is to be obtained when soundings are made without tubes.

Automatic brake cords are of special cord, and spares are supplied. The cord may be oiled to prevent rotting.

The 'V' groove must be kept free from rust and dirt.

TO TAKE A SOUNDING WITH A CHEMICAL TUBE

1. Place the chemical tube in the brass guard, open end down, and replace the cap which fits in position with a bayonet joint.

2. Put the sinker over the side and haul the traveller out to the end of the boom. The wire must be veered to prevent the swivel's jambing in the traveller. This can be done in two ways:

(*a*) By slipping the brake.

(*b*) By withdrawing the steel ball. A push switch on the forward side of the machine energises a solenoid which withdraws the ball, and so allows the ratchet wheel to turn, and the wire to be veered with the brake on.

The magnet is not strong enough by itself to withdraw the ball, but once the ball is pushed out (for example with a pencil) the magnet will hold it clear of the ratchet wheel.

3. Lower the sinker until it almost touches the water.

4. At the order to let go, give the hand wheel half a turn in the direction of veering.

5. Press the feeler on to the wire as it runs out. In deep water a strong pressure is required to 'feel' bottom.

6. Bottom will be felt by the wire's slacking up, and when this occurs the brake must be put on by giving the hand wheel a half turn in the direction of heaving in. At the same time the dial reading of the number of fathoms of wire out must be noted.

7. Put the motor switch right over to the 'on' position. The solenoid is energised by this operation and holds the ball clear of the ratchet wheel while the tube is hove in.

8. Guide the wire on to the drum with a pad of oiled canvas, or Russian tallow, taking care to prevent any kinks.

9. When the lead is nearly home, ease the switch back gradually and heave in the last few fathoms by hand.

10. Haul the lead to the ship's side; take the chemical tube from the guard and holding it vertically, place it in the boxwood scale from which the depth may be read off.

11. The following corrections must be applied before the depth obtained can be compared with the chart.

(*a*) *Barometer*. If the reading is under 999 mb., nil.

Barometer	1007.	Add 1 fathom in 40.
,,	1010.	,, ,, ,, ,, 30.
,,	1033.	,, ,, ,, ,, 20.
,,	1050.	,, ,, ,, ,, 15.

These corrections are stamped on the back of the later-pattern boxwood scales.

(*b*) *Tide*. Subtract the height of the tide at the time the sounding was taken.

Chemical Tubes are coated with chromate of silver which gives them a red-brown colour. When a sounding is taken salt water is forced up the tube by pressure, and this action turns the inner surface white.

Tubes are supplied in a wooden box containing 10 tins, each tin containing 10 tubes, and they must be kept in a dry place. Used tubes should never be stored with unused tubes. Special tubes are supplied for fresh water, and if these are unobtainable, a pinch of dry salt should be put in the ordinary tube before it is inserted in the container. Owing to deterioration, tubes should be returned if still unused 18 months after issue.

Causes of Bad Cuts

1. An incorrect length of stray line and consequent incorrect position of the guard tube.
2. Allowing the wire to over-run and the tube thus to lie horizontally on the sea bottom.
3. Taking off the brake or applying the brake too suddenly, thus jerking the water up and down in the tube.
4. Not keeping the tube vertical when removing it from the guard.
5. Condensation in the tube. If there is a large difference between sea and air temperatures, immerse the tube in a bucket of water, with the open end at least one inch above the surface.
6. A very soft bottom causing the lead to oscillate.

Ground Glass Tubes. Another type of sounding tube which can be used with any sounding machine, has the inner surface ground instead of being coated with a chemical.

The ground glass shows clear when wet, and the tube can be used an indefinite number of times if it is thoroughly dried. A detachable rubber cap seals the upper end and is removed when the tube requires drying.

These tubes, in addition to being economical, have the advantage of being equally satisfactory in both fresh water and salt water.

To Sound without Tubes. The procedure is similar to sounding with tubes, with the following exceptions.

1. Before letting go, the pointer on the dial must be set to zero. If the full 300 fathoms is not on the drum, the pointer must be set to the number of fathoms missing. This length is subtracted from the reading when the lead touches the bottom. The dial graduations are not evenly spaced because, as the diameter of the drum decreases, one revolution runs off less wire.
2. When the lead touches the bottom, note the dial reading of the number of fathoms of wire out.
3. The vertical depth is found by entering the *Speed and Depth Table* given on page 196, or in the maker's handbook, with the

speed of the ship and the amount of wire run out. This table will not, as a rule, apply to individual ships unless some small adjustments are made to meet their peculiarities, and a series of graphs for different speeds should be constructed by using the following method.

Take three soundings by tube, if possible with large variations in depth between them, and on each occasion observe the amount

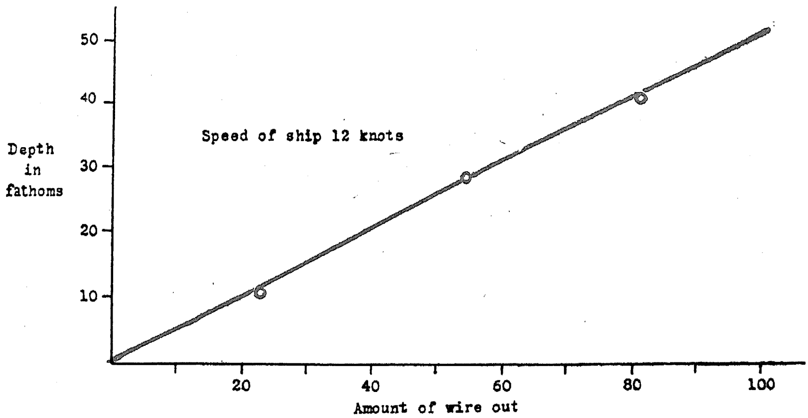


FIGURE 82.

of wire run out. Correct the soundings and plot them against the amount of wire run out, as shown in figure 82. The graph should be a straight line, passing through the origin. Tubes need not be used in subsequent soundings, the vertical depth being found by entering the graph with the amount of wire out. This graph will hold good only if the ship does not alter speed.

NOTE. 1. The machine may be used as a hand machine by slacking up the bolts securing the frame, which fit in elongated slots, and moving the frame bodily sideways. This withdraws the gear wheel from the raw hide pinion on the armature shaft. These slots may also be used for taking up backlash between the gear wheel and the rawhide pinion.

2. The dial is lighted. The operating switch is on the fore side, next to the push for the solenoid.

3. To avoid jambing, never leave the main brake set up when sounding is completed.

4. All soundings taken should be entered in the *Sounding Book.*

SPEED AND DEPTH TABLE

MACHINE, Kelvin's Mark IV. or Motor.
SINKER, Kelvin's M.C. I. with lead core, weight 24 pounds.
HEMP LINE, 12 feet long.
WIRE, seven-strand.

AUTOMATIC BRAKE WEIGHT, 6 pounds.
WIRE LED THROUGH Kelvin's carrier and block.
GUARD TUBE, seized on 3 feet above eye of sinker.

Approx. Vertical Depth.	FATHOMS OF WIRE RUN OUT. Speed in Knots.							
	6	7	8	9	10	11	12	13
Fms. 5	6½	7	7½	8½	9½	10	10½	14
6	7½	8	9	10	11½	12½	13	16
7	9	10	10½	12	13½	14½	15	18
8	10½	11½	12	13½	15	16	17	20
9	11½	12½	14	15½	16½	18	19	22
10	13	14	15½	17	18½	20	21½	24
11	14½	15½	16½	18	20	21½	23	26
12	15½	16½	18	19½	21½	23	25	28
13	17	18	19½	21	23	25	27	30
14	18	19½	21½	23	25	26½	28½	32
15	19½	21	23	24½	26½	28½	30½	34
16	20½	22½	24½	26	28	30	32½	36
17	22	24	26	28	30	32	34½	38
18	23	25	27½	29½	31½	34	36½	40
19	24½	26½	29	31	33½	36	38½	42
20	26	28	30½	32½	35	37½	40½	44
21	27½	29½	32	34½	37	39½	42½	46
22	28½	31	33½	36	39	42	45	48
23	30	32½	35	38	41	43½	46½	50
24	31	33½	36½	39½	42½	45½	49	52
25	32½	35	38	41½	45	48	51	54½

Approx. Vertical Depth.	FATHOMS OF WIRE RUN OUT. Speed in Knots.							
	6	7	8	9	10	11	12	13
Fms. 26	33½	36½	39½	43	46½	49½	53	56½
27	35	38	41	44½	48½	52	55½	58½
28	36	39	42½	46	50	53½	57½	61
29	37	40	43½	47½	52	56	60	63
30	38½	41½	45	49	53½	57½	62	65
31	40	43	46½	51	55½	60	64½	
32	41	44½	48	52½	57	62	67	
33	42½	46	49½	54	59	64	69	
34	43½	47	51	55½	60½	66	71½	
35	45	48½	52½	57½	62½	68	74	
36	46	50	54					
37	47½	51½	55½					
38	48½	52½	57					
39	50	54	58½					
40	51	55½	60					
41	52½							
42	54							
43	55							
44	56½							
45	58							

These tables should not be implicitly relied upon until sufficient experience has been gained to enable an opinion to be formed about their trustworthiness when they are used with different machines. See remarks concerning sounding without tubes.

THE NAVIGATIONAL RANGEFINDER

Type F.T. 32. Base length 80 centimetres.
This instrument is fully described in O.U. 5242.

THE WEYMOUTH COOKE SEXTANT RANGEFINDER

This instrument provides a means of obtaining :

1. a *range* of an object when either the height or length of the object is known ;
2. a *height* or *length* of an object when the range is known.

WEYMOUTH COOKE SEXTANT RANGEFINDER.

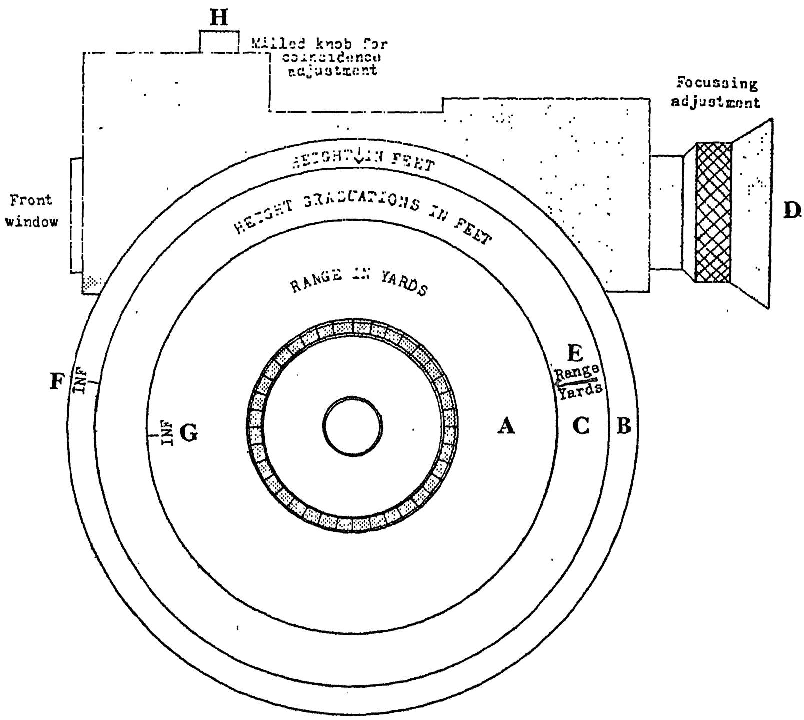


FIGURE 83.

Description. The face of the instrument has three rings as shown in figure 83.

1. The range ring A to which is attached the working head, graduated in yards from 1,200 to 18,000, also an infinity mark, G.
2. The fixed ring B which carries the height scale index and an infinity mark, F.
3. The height ring C, which can be moved round relative to A and B, and carries the range scale index E. It is graduated in feet from 15 to 200.

The telescope is of fixed power and is focussed by rotating the eyepiece D.

Coincidence Error and its Adjustment. The only error is that of coincidence and the instrument should always be tested and adjusted before use.

To Test and Adjust for Coincidence

1. Set the *red arrow* E on the height scale ring C in line with the *infinity mark* F on the fixed ring B.

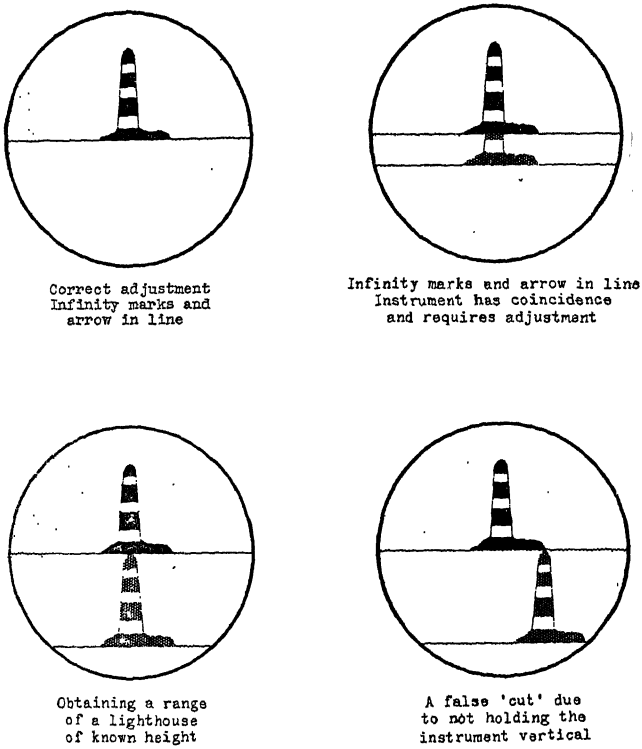


FIGURE 84.

2. Revolve the working head A clockwise until it is brought up by the limit stops; then turn it back a small amount and bring the infinity mark G into line with E and F.

3. Select a suitable object at close range; focus the telescope and observe the object with the instrument. If the shadow image overlaps, as shown in figure 84, there is coincidence error and it must be removed by turning the milled head H, which is under a protecting cap on the top of the casing over the window, until only one clearly defined object can be seen.

The position of the height ring C during the above procedure is immaterial.

To Take a Range of an Object

1. Set the height of the object on the height ring C in line with the height pointer on the fixed ring B.

2. Look through the telescope at the object; move the working head A until the shadow image is seen, and continue moving it until the upper edge of the shadow image coincides with the lower edge of the normal image as shown in figure 84. The view through the eyepiece will be similar to the view when angles are measured with a navigational sextant.

3. Against the red arrow on the height scale C read off the range on the range scale A.

4. To take a range less than 1,200 yards, double the height setting and halve the range result.

NOTE. (*a*) When using the instrument in the vertical position, take care to hold it vertically, with the lower image directly under the upper image; otherwise a false cut will be obtained as shown in figure 84.

(*b*) To measure a height or a length, the rings must be moved in the reverse order; that is, take a cut with the working head; move the height ring until the correct range shows against the range index, and then read off the height or length against the height index.

(*c*) This instrument is limited to measuring an angle of 6° and is therefore unsuitable for use in circumstances where the angles are greater.

STUART'S DISTANCE METER

This instrument measures the distance of an observer from an object of known height and is useful for station keeping in a fleet or for anchoring or mooring on another ship.

It consists of a long curved lens attached to a radial distance scale graduated from one-quarter to 30 cables. Both the curved lens and the distance scale are mounted in a slide, which can be moved up and down in a vertical direction by a milled headed pinion, working a ratchet.

Across the movable distance scale is a fixed horizontal metal bar, which is graduated from 0 to 220 feet. On this bar is a sliding pointer, the left hand edge of which should be set to the height of the observed object.

One edge of the curved lens moves alongside a fixed wedge-shaped lens mounted in an aperture in the frame of the instrument. A small telescope, fitted with an interrupted thread, is provided and can be inserted in a metal collar; when it is in place, its field includes the centre of the fixed lens and a portion of the movable lens. The telescope should be focussed after being fitted in the instrument.

To Observe. Set the pointer to the height of the top of the object above the water line or above the base of the object, whichever is being used. Move the slide up or down, by turning the milled head of the pinion, until the top of the object, as seen through the right or moving lens, is in line with the water line or the base of the object, as seen through the left or fixed lens. Where the pointer

cuts the radial distance scale is the distance of the observer from the object.

On the reverse side of the instrument, opposite to the distance scale, is a skeleton table on white celluloid where the masthead heights of ships can be recorded in pencil.

NOTE. When it is not possible to see the waterline directly beneath the object, as for example, when station is being kept on the foremast of a ship ahead, some point must be chosen to give the correct angle. This point is generally known by experience and may be, for example, the base of the after turret or the quarter-deck level. It can be found by taking a rangefinder range of the mast; setting this range on the distance meter; then looking through the telescope and observing where the top of the masthead cuts the hull of the ship.

COURSE RECORDING INSTRUMENTS

These are of two types :

1. *The Brewerton course recorder.*
2. *Plotting Instrument Mark V.*

THE BREWERTON COURSE RECORDER

This instrument consists of three elements. The chart board, the controller, and the plotter (called the ' crawler ').

The Chart Board consists of an iron plate mounted on a wooden frame on which is laid the chart or other paper.

The Controller is fixed on the side of the table, and by working in conjunction with the gyro compass and the log, controls the direction and distance in which the plotter pencil moves over the paper on the chartboard.

The Plotter is that part ot the instrument which crawls over the chartboard. It has two pairs of magnets mounted at right angles to each other in a circular framework, each pair being alternately attached to the iron plate.

A vertical axle is connected through the gearing with a horizontal shaft to a motor in the controller by which it is made to rotate relatively to the magnets.

When the axle is rotating and one pair of magnets is fixed to the board, the plotter remains stationary, but the other pair of magnets is moved to a new position. When this second pair holds the table the first pair is moving, carrying with it the axle and plotter. The plotter is therefore alternately at rest and in motion, and the pencil makes a series of small arcs.

The revolutions of the horizontal shaft connecting the controller and the plotter axle are made proportional to the revolutions of the log in the controller.

The direction of motion depends on the point in each revolution at which one pair of magnets releases its hold and the other grips. This action is controlled by a gyro repeater.

A 'dummy log' is fitted into the mechanism, and this will drive the plotter at any desired speed should the ship's log break down or prove unreliable.

The current to the magnets can be shut off to allow the plotter to be moved to a new position, and a switch is supplied to make the driving motor run continuously and permit the direction of motion of the plotter to be checked.

Arrangements are made for adjusting the motion of the plotter to compensate for errors in the log, an error up to 8 per cent. being allowed for.

If the log reads too low the corrector must be set to 'fast'.

Scales. Later patterns have a variable scale. Older patterns are fitted with three separate scales, 1, 2 and 5 miles to the inch.

Light Indicator. A glass cover is mounted above the chartboard, and when plotting is done by hand, a plotting sheet is pinned over the glass.

A small lamp, fitted to the automatic plotter, throws a vertical spot of light through the glass and plotting sheet, thus indicating the ship's position on the hand plot.

NOTE. (*a*) The plotter is liable to be displaced by gunfire.
(*b*) If it is necessary to inspect the track or to plot on the chart board, then the track must be plotted by hand while the plotter is raised.

PLOTTING INSTRUMENT, MARK V

This instrument was formerly called the A.R.L. Table and is now being fitted to all new construction. It is fully described in the *Naval Electrical Manual, Volume II.*

THE BATTENBERG COURSE INDICATOR

This instrument is practically a mooring board in mechanical form, and is designed for the rapid solution of a series of ordinary speed and distance triangles frequently met with in fleet work.

A full description of the instrument and examples of various problems will be found in O.U. 5274.

When in company with other ships, the officer of the watch should always have the instrument on the bridge and set with:

1. the course and speed of the guide;
2. the speed available in his own ship;
3. the position of his ship relative to the guide.

THE STATION POINTER

Full details are given in the handbook supplied with each instrument.

A station pointer, shown in figure 85, consists of a graduated circle and three arms, the bevelled edges of the latter radiating from the centre of the circle. The centre leg, OA, is fixed and its

bevelled edge corresponds to the zero of the graduation of the circle which is marked at every half degree, from 0° to 180° on either side. The two outer legs OB and OC (called the left and right legs) are movable and can be clamped in any position.

Station pointers used in surveying are fitted with a vernier on each movable leg which will read to 1 minute.

The centre of the circle is indicated by a small nick in the bevelled edge of the fixed leg. When the instrument is used, a sharp pencil point is essential in order that the mark made on the chart may exactly correspond with the centre of the instrument which is on the continuation of the edge of the fixed leg.

The bevelled edge of the right leg cannot be brought very close to that of the centre leg. For this reason, when the right-hand angle is very small, and consequently the right leg cannot be set to it, the left leg should be set to the small angle ; and the right leg

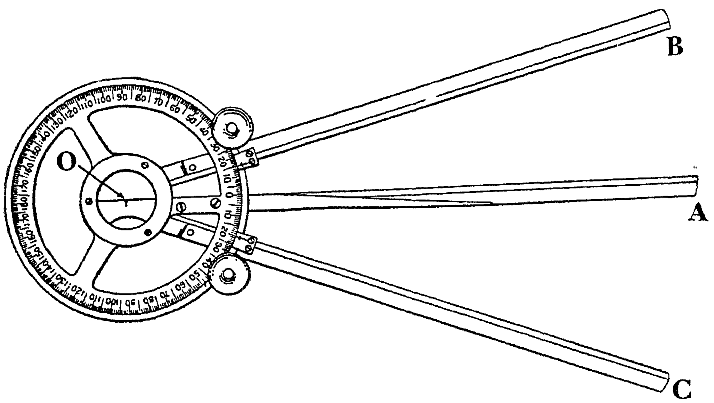


FIGURE 85.

should be moved round and set to the sum of the right and left angles measured from the fixed leg to the left. In these circumstances the fixed leg should be directed to the right-hand object.

Testing. Station pointers should frequently be checked for accuracy. Chart 5007, *Diagram for Testing Station Pointers, Protractors, etc.*, is supplied with chart sets for this purpose. The instrument should be placed on the diagram with the nick exactly at the centre of the radiating lines, and the bevelled edge of the centre leg OA along the zero line. The movable legs should then be moved to coincide with the lines each side of the zero, and the error corresponding to the various angles read off, the sign + or − being given according to the direction in which these various angles must be applied to the observed angle.

These errors should be tabulated and pasted in the lid of the box.

An alternative method of testing without the diagram 5007, is to draw radiating lines by chords, the angle between the adjacent

lines being 10 degrees. Having thus constructed the diagram, proceed as above.

While the instrument is being tested it should be noted whether the bevelled edge of each leg coincides throughout its whole length with one of the straight lines.

In certain circumstances, the station pointer becomes awkward to use. For instance, the charted positions of the observed objects may be hidden under the rim of the instrument, or the sides of a small chart table may prevent the arms of the instrument from being moved to the correct position on the chart. When this occurs, it is better to lay off the angles on a Douglas protractor.

THE DOUGLAS PROTRACTOR

This instrument is a transparent square protractor, graduated all round in degrees from 0° to 360° in both directions, clockwise and anti-clockwise. One side has a smooth surface and the other a matt surface to facilitate laying off angles in pencil. In the centre is a small hole through which a pencil dot can be made to mark the observed position, when the protractor is used as a station pointer.

Uses of the Douglas Protractor

1. Laying off angles in a similar way to using a station pointer.
2. Finding the error of the gyro compass. To do this, the bearings of three shore objects must be drawn on the protractor thus giving the ship's position. Then the amount the zero of the protractor is directed away from north is then the error of the gyro compass.
3. Finding the ship's position from a series of bearings of a single object. On one edge of the matt surface mark off the distance the ship has run on the scale of the chart between the bearings. Lay off the bearings on the chart. Place the protractor over the bearings and adjust it until the bearings pass through the points on the edge of the protractor which have corresponding times. This will give the course made good, an indication of the tidal stream and the position of the ship. It will also help to discard any unreliable bearings, particularly when D/F bearings are plotted.
4. Finding the ship's position from a line of soundings.

CHAPTER IX

GYRO COMPASS

'The Navigating Officer is to be in charge of, and responsible for, the efficient running of the gyro compass equipment. A suitable electrical rating will be detailed by the Torpedo Officer to assist him in the care and maintenance of the equipment. In ships where qualified navigating officers are not carried, the Captain will be responsible and will detail an officer to take charge of the gyro compass equipment.' K.R. & A.I., Articles 1190 and 1244 (6).

The theory, construction and maintenance of the Sperry gyro compass are fully described in the *Admiralty Manual of the Sperry Gyro Compass*, 1931 and *Addendum*, 1936.

This chapter gives practical notes on the running of a gyro compass in a ship, and only a brief summary of the theory.

The Sperry gyro compass is now considered to be the principal direction indicator in H.M. ships, and is an essential unit of all ships of the fleet. It is also invaluable in keeping the numerous control instruments set to the course of the ship, a function which it readily fulfils because its readings can be repeated in all parts of the ship by a simple electrical device.

SUMMARY OF THE THEORY OF THE SPERRY GYRO COMPASS

The Motion of a Free Gyro. If a heavy wheel could be mounted so that it is free to spin about its axis, tilt and turn in azimuth, its axis would maintain a fixed direction in space when the wheel is rotated at high speed, because there are no forces to alter its direction. Such a wheel is called a free gyroscope, or free gyro.

Since the direction of any star from the Earth may be considered fixed, the axis of a free gyro would follow the apparent motion of a star relative to the Earth, this motion resulting from the rotation of the Earth on its axis.

It would describe a circular path round the celestial pole, rising if east of the meridian and falling if west of the meridian. At the bottom of its path, as it crosses the lower meridian, it would cease to fall and begin to rise.

If the axis of a free gyro in north latitude were pointed at the north point of the horizon, it would thus immediately drift east and tilt up, the rate of tilt increasing as the azimuth increases, and during the course of the day it would describe a complete circle round

the celestial pole. The important point to realize, however, is that the axis would first drift east, and it is important because, if the gyro is to be any good as a compass, its axis must remain horizontal and not leave the meridian ; that is, this easterly drift must be counterbalanced by an equal westerly precession introduced by some mechanical device. This mechanical device is known as a *gravity control.*

The Gravity-Controlled Gyro Compass. In compasses now supplied to H.M. ships, the westerly precession necessary to balance the easterly drift described above is provided by the *latitude rider.* This is simply an adjustable weight attached to the south side of the casing.

If the gyro axis were pointed at the north point of the horizon, and not disturbed, the latitude rider alone would keep it in line with the meridian. Any disturbance, however, would start a wander and the gyro would be useless as a compass.

Control by *mercury boxes* is the method adopted in the Sperry gyro compass for correcting any disturbance of the compass and compelling it to settle on the meridian.

The mercury boxes are attached to the compass in such a way that any tilting of the axis above the horizon brings into play a gravity torque which moves the axis in a westerly direction. Conversely, a tilt-down below the horizon causes an easterly movement of the axis.

Accompanying these precessions in azimuth are small variations in tilt introduced for damping purposes.

The movements described—namely :

1. apparent motion due to the Earth's rotation,
2. precession in azimuth caused by the latitude rider,
3. precessions in azimuth and variations of tilt caused by the mercury boxes,

—combine to make the north end of the gyro axis describe a very flat spiral path. The centre of the spiral is the *settling position,* which the compass reaches if disturbed, after one or more damped oscillations of 87–90 minutes' duration.

Unless the tilting movement resulting from the Earth's rotation is sufficient, the mercury control will not be effective.

The tilting movement is a maximum at the equator and zero at the poles. Hence the compass loses its directive power as the latitude increases, and ceases to function adequately beyond about 70°N. or S.

Speed Error and Ballistic Deflection. The northerly component of the ship's speed creates a small torque causing the compass to point west, for the same reason that the Earth's easterly rotational speed gives the compass its north-seeking property. Hence there is a deflection of the compass, called *speed error,* depending on the ship's course, speed, and latitude. By means of the *speed corrector*

SUMMARY OF PARTS AND CONNEXIONS OF THE SPERRY GYRO COMPASS

Classification		*Part*	*Connexions*	*Remarks*
OUTER MEMBER		Binnacle outer ring		
			Binnacle springs	To absorb shocks caused by gunfire, etc.
		Binnacle inner ring		
			Gimbal pivots and bearings	To allow for the roll of the ship
		Gimbal ring		
			Gimbal pivots and bearings	To allow for the pitch of the ship
		Spider		
INNER MEMBER			Upper and lower stem bearings	To allow the phantom to turn in the spider
		Phantom		
			Suspension and guide bearings	To allow the vertical ring to turn in the phantom
	SENSITIVE ELEMENT	Vertical ring		
			Horizontal bearings	To provide the tilting freedom of the rotor casing
		Casing		
			Rotor bearings	To provide the spinning freedom of the rotor casing
		Rotor		

NOTE. The mercury boxes form a connexion between the phantom and the rotor casing. They may, therefore, be considered as part of both the inner member and the sensitive element.

mechanism, combined with the *cosine ring*, the lubber ring is turned through the appropriate angle and the compass shows correct readings.

The compass immediately takes up the new settling position consequent on any alteration of course or speed. The reason for this is that the acceleration of the compass with the ship during the alteration causes a flow of mercury from one box to the other in such a way that the compass precesses in the required direction. This precession is called *ballistic deflection*. The mercury boxes are so designed that the ballistic deflection equals the speed error.

Accompanying the ballistic deflection is a small precession in tilt arising from the method of damping. This is a source of a small uncorrected wander which may reach 2° in extreme latitudes with high speeds.

Rolling Errors. Errors brought about by the bodily accelerations of the compass when the ship is rolling are eliminated by fitting compensator weights on the sensitive element giving symmetry of mass, and retarding the flow of mercury from one box to the other so that the torques caused by swinging the compass are not cumulative. This retardation is effected by using a small-bore pipe to connect the mercury boxes.

SUMMARY OF THE ELECTRICAL SYSTEM

A.C. System. The rotor is spun by an alternating current of 90 volts. It takes about 50 minutes to attain its running speed of 8,600 r.p.m. and about 5 hours to come to rest after the current is broken. A special switch is fitted to stop the rotor in about 50 minutes if required.

D.C. System

1. The azimuth motor and transmission to the repeaters is operated by a direct current of 20 volts. The source of supply differs slightly in various equipments but the supply is always supported by a 20-volt battery.

2. An alarm bell and warning lamp are operated from the 20-volt system through a resistance or from a separate battery.

THE ALARM SYSTEM

The object of the alarm system is to call attention to faults in the A.C. and D.C. supplies to the compass and to failures in the follow-up. It also protects the compass from any damage that might be caused by a failure in the follow-up.

The alarm bell is made to ring, and the red warning lamp on the bridge burns whenever any of the following faults occur :

1. Drop or failure in the ship's supply or blowing of the A.C. motor generator fuses. This fault is indicated by a zero reading on the A.C. meters.

2. Drop or failure in the 20-volt supply from the dynamotor or

blowing of the 20-volt fuses. This fault is indicated by the D.C. meters on the panel.

3. Failure of the follow-up system. This is indicated by the absence of ' hunt ' in the master compass.

Whenever one of these faults occurs, the alarm bell rings and the warning lamp on the bridge burns and they continue to do so even if the fault corrects itself.

If the fault still exists, the bell can be stopped by switching off the supply to the alarm systems. After the fault has been corrected the alarm relay and the alarm circuit should be re-set.

If the 20-volt supply fails, the compass should continue to be supplied from the battery and should not, therefore, be disturbed.

A failure in the follow-up, however temporary, will disturb the compass. *If, therefore, the alarm bell rings because a failure of the follow-up has occurred, the compass cannot be relied upon until it has had time to re-settle.*

STARTING ROUTINE

It is important that the compass should be started at least 5 hours before it is required for navigation.

Before the compass is started, the following points should be checked.

1. The vacuum should be the best obtainable; that is, an efficient pump should be used when the compass is hot.
2. The casing clamp should be engaged.
3. The latitude rider should be set to the required latitude. If the compass is fitted with the Sperry type corrector mechanism, the latitude levelling dial and the latitude dial of the corrector mechanism, should be set to the required latitude.
4. The corrector mechanism should be set to zero. If the compass is fitted with the Sperry type corrector mechanism, the speed dial of the corrector mechanism should be set to zero.
5. The setting of the mercury boxes should be adjusted to the required latitude.
6. The azimuth motor and alarm circuits should be tested.
7. The compass should be set approximately to the ship's head.

To Start the Compass. Carry out the following operations in the order given.

1. Make the ship's supply to the panel, and, in submarines only, make the voltage regulator switch.
2. Make the A.C. generator switch. This should start the rotor. The correct direction of rotation is checked by the spiral's being seen to rise when viewed through the window.
3. After an interval of about 20 minutes :
   (*a*) disengage the casing clamp.
   (*b*) make the 20-volt supply to the compass, which should start the ' hunt '.

(*c*) set the alarm relay by pressing up the push and set the alarm indicators where fitted.
(*d*) switch on the alarm system and test the operation of the azimuth release relay by bridging the alarm contact on the master compass, thereby causing the motor to stop, the clutch to be released and the alarm bell to ring.
(*e*) re-set the alarm relay.
(*f*) centralise the bubble of the east level by applying a light pressure to the east trolley in the opposite direction to that in which it is required to move the bubble.
(*g*) re-set the compass to the ship's head by pressing down on the north or south mercury box.
(*h*) switch on the 20-volt battery where fitted and adjust the D.C. rheostat until the D.C. volt-ammeter shows that the battery is just on charge.

4. After the compass has been running for an hour the rotor should be up to its full speed of 8,600 r.p.m. This should be checked, if necessary, by using a stroboscope, though normally, if the ship's supply and the vacuum remain constant, it is sufficient to make certain that the A.C. meters are showing their normal readings (usually about 1·2 amperes and 90 volts). If any alteration is required, the gyro speed-rheostat should be adjusted so as to give the correct speed.

5. Synchronise the repeaters and make the repeater switches, adjusting the D.C. rheostat to maintain 20 volts at the panel.

6. On leaving harbour, set the corrector mechanism according to the table of speed and latitude supplied. If the compass is fitted with the Sperry type corrector mechanism, set the speed dial.

STOPPING ROUTINE

1. If the compass is no longer required, all switches should be turned to the *off* position, and the casing clamp engaged.

2. When it is required to stop the rotor quickly for any purpose, for instance, checking the balances, the A.C. generator switch should be reversed, all the other switches being turned to *off*, the casing clamp being engaged as before.

After 30 minutes, the compass should be watched in order that the A.C. generator switch can be turned to *off* immediately the rotor has stopped.

SOME CAUSES OF DEFECTIVE WORKING OF THE COMPASS

Compass Wandering. This may be caused by:

1. *fouling* between:
   (*a*) the casing clamp and the phantom.
   (*b*) the phantom and the spider, especially at the damping weight on the azimuth motor shaft.
   (*c*) the trolley frame, and the contactor support.

(*d*) the phantom and the mercury-box pipe or the mercury-box pivots and the bearing housing.
(*e*) the three-phase conductor leads and the phantom or the vertical ring.
(*f*) the binnacle cable and the inner member.
(*g*) the compensator weight frame and the sides of the phantom slots.
(*h*) the screws securing the east–west inner member balance weight and the vertical ring.
(*i*) the clover-leaf connexion leads and the top of the casing.

2. *friction* at :
(*a*) the upper and lower guide bearings.
(*b*) the horizontal bearings, if the clearance is not correct.
(*c*) the mercury box bearings.

3. *any error in the compound or vertical balances :* any slacking back of the compensator weight lock nuts or of the lower guide pivot screws will affect the vertical balances.

4. *the gimbal dampers* of the band-brake type being *on* when the ship is not rolling or pitching.

5. *dirt in the mercury :* this usually causes a wander which starts when the ship gets under way.

TEMPORARY CHANGES IN THE AZIMUTH OF THE SETTLING POSITION

These may be caused by :

1. *slacking back of :*
(*a*) the horizontal running balance weight.
(*b*) the adjusting tongue damping screw at the top of the suspension.
(*c*) the radial screws holding the housing of the upper guide bearing. [These screws should not be set up too tightly.]

2. *incorrect compound balances of the outer member :* these cause a change in the settling position, which varies with the course.

PERMANENT CHANGES IN THE AZIMUTH OF THE SETTLING POSITION

These may be caused by :

1. a twist in the suspension.
2. an error in the horizontal running balance.

Failure may be Caused by :

1. slacking of the azimuth motor relay in its bracket, or wrong adjustment of the gaps of the spring contact arms.
2. slacking of the trolley-table clamping screws.
3. dirty follow-up contacts or azimuth-motor relay contacts.

CARE AND MAINTENANCE

Cleanliness and freedom from dust are essential conditions for the efficient operation of the gyro compass, and it is most necessary that the maintenance routine and instructions, given in Chapter XIX of the *Admiralty Manual of the Sperry Gyro Compass*, should be strictly adhered to.

INSTRUCTIONS, USE OF FORMS, REPORTS, ETC.

The attention of officers in charge of gyro compass equipments is directed to K.R. and A.I. Article 1214, and to the various *Admiralty Fleet Orders*, of which a considerable number affecting gyro compasses are in force.

A form is included as an Appendix to Chapter XX of the *Admiralty Manual of the Sperry Gyro Compass*, on which it is intended that the number of A.F.O.s, local orders, etc., shall be noted, for reference to the various orders in force.

The general instructions for drawing gyro stores, returning an equipment, overhauls, etc., are given in publication B.R. 35, *Sperry Gyro Compass Equipment. General Instructions regarding Supply and list of Spare Parts and Accessories*, which contains, also, a great deal of other useful information about gyro compasses.

There are a number of technical officers on the staff of the Compass Department, Slough, part of whose duties consists in visiting H.M. ships fitted with gyro compasses to advise the officers of the ship, arrange overhauls, repairs, replacements. They also test or adjust equipments when necessary.

When trouble is experienced, the commanding officer should communicate with the Director of the Compass Department, Slough, reporting the nature of the fault and asking for advice or for a representative to be sent to inspect the equipment.

The same procedure should be followed before the ship arrives at her Home Port for refitting or paying off. The Director of the Compass Department will, on receipt of his representative's report, decide on the nature and extent of the overhaul to be undertaken and make the necessary arrangements with the dockyard for the defective parts to be removed and taken in hand.

On the Mediterranean Station, application should be made to the Superintendent of Gyro Compasses, Malta, who will carry out a similar routine.

Use of Form S. 377. Whenever a communication concerning the defective working of a gyro compass is sent to the Director of the Compass Department or Superintendent of Gyro Compasses, Malta, a report of the operation of the compass in question should be prepared on form S. 377, and attached to the report.

This form of report, if carefully filled in, gives a great deal of information which is invaluable to the Compass Department when analysing the defect.

Form S. 377 is also to be rendered after installation of a master compass or the fitting of a new control, as a record that the equipment has been properly installed and is functioning correctly.

Forms S. 1177 and S. 1177a. (The Gyro Compass Log.) The report which has to be forwarded quarterly to the compass department, through the senior officer, should be carefully filled in and should contain full details of all breakdowns, defective working, replacements, etc. These reports when received at the compass department are carefully studied and recorded. A well-kept record is not only useful for diagnosing a fault, but frequently gives timely warning that some defect is developing, in which event a representative of the compass department is sent to confer with the ship's officers and make proposals for replacement or repair.

GYRO COMPASS ERROR

'The Captain, Navigating and other Executive Officers of the Ship are to keep a constant watch over the errors and deviations of the compasses, and they are to make themselves thoroughly acquainted with the practical rules relating thereto as given in the Admiralty Manuals.'

'Special attention is directed to the necessity for observing, when possible, the errors of the standard and gyro compasses on each course steered and recording them in the *Navigational Data Book* and *Gyro Compass Log*, respectively, and in the *Deck Log.*'—K.R. and A.I. Article 1187.

The error of the gyro compass can be found by :

1. taking a gyro bearing of a transit, the true bearing of which is known.
2. taking an azimuth of a heavenly body and working out the true bearing.
3. taking a bearing of a distant object whose bearing is known.
4. using a station pointer or Douglas protractor in the way described on page 203.

NOTES ON THE GYRO COMPASS

General

1. Make certain that the care-and-maintenance routine laid down in the *Admiralty Manual of the Sperry Gyro Compass* is fulfilled.
2. Before the ship refits or pays off, inform D.C.D., Slough, giving plenty of notice.
3. If any trouble is experienced, inform D.C.D., Slough.
4. Keep the *Admiralty Manual of the Sperry Gyro Compass* up to date by A.F.O.s.
5. Check, periodically, the lubber line of the bearing repeaters.

Starting

1. Start the master compass 5 hours before it is required for use.

2. Take care to follow the starting routine, described in this chapter and in the *Admiralty Manual of the Sperry Gyro Compass.*

At Sea

1. Memorise the alarm system so as to be quite certain what to do if the alarm bell rings or the red lamp burns.

2. Check the compass :

(*a*) as soon as possible after the ship is under way ;
(*b*) after the ship has made her first large alterations of course ;
(*c*) at frequent intervals, when practicable.

3. Remember that when the ship's speed is altered, the new speed must be set on the master compass. When, therefore, the ship is manœuvring with many speed alterations, it will be necessary to have someone stationed at the master compass.

4. If the compass is fitted with an Admiralty speed corrector, the speed setting must be taken from the special table fixed to the pelorus stand.

5. In rough weather put on the band-brake type gimbal dampers (if fitted).

On Change of Latitude. A correction will need to be made to the following parts :

1. *Mercury Boxes.* With ' D ' type boxes, the domes may be set to the required latitude at any time.

With the older type of boxes, the valves can be set only in harbour, with the wheel running.

2. *The Corrector Dial of the Admiralty Type Corrector Mechanism* or the latitude dial of the Sperry type mechanism.

3. *The Latitude Rider.* (If a Sperry type mechanism is fitted, the latitude levelling dial will require adjusting.)

CHAPTER X

MAGNETIC COMPASS

The theory of this subject is fully dealt with in Volume III. The purpose of this chapter is to lead up to the practical correction of a well-placed compass.

MAGNETISM

Certain substances, such as iron ores and lodestone, have the property of attracting and repelling one another, and of being attracted by other pieces of iron and steel. This property is called *magnetism*, and these substances are called *natural* magnets.

Artificial magnets can be manufactured having the same properties as natural magnets. They are made of a certain kind of steel with the addition of 5 per cent. tungsten, by rubbing them with another magnet or magnets, by hammering them in a magnetic field or by means of an electric current.

A compass needle is an artificial magnet, suspended so as to remain nearly horizontal, and it points always with one end towards the north. This end is called the **North-Seeking or Red End.** The other end is called the **South-Seeking or Blue End.**

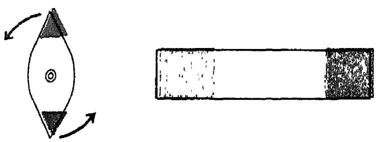


FIGURE 86.

The attractive force of a magnet is concentrated at definite points near the ends, called **Poles.** The red end contains the **Red Pole** and the blue end contains the **Blue Pole.**

NOTE. A magnet always possesses two poles. A red pole cannot exist without a blue pole, or a blue pole without a red. If a magnet is broken each part becomes a separate magnet.

If a magnet is placed near a compass needle, as shown in figure 86, the red pole of the magnet attracts the blue pole of the compass needle. Similarly it repels the red pole of the compass needle. Hence the fundamental law of magnetism : *unlike poles attract and like poles repel.*

If a magnet is placed at right-angles to a compass needle, as shown in figure 86, it exerts a magnetic couple tending to turn the

FIGURE 87.

compass needle until the needle is parallel with it. If it is placed in line with the needle, as shown in figure 87, it has no turning effect.

Magnetic Field. The region under the influence of a magnet is

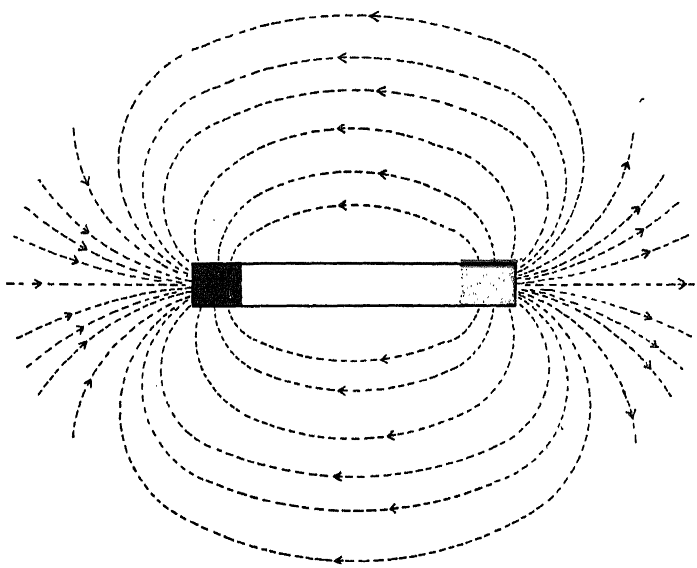


FIGURE 88(a).

called the *magnetic field*. This field is made up of **Lines of Force** which leave the red pole and enter the blue pole, as shown in figures 88 (a) and 88 (b), and thus indicate the paths which could

be traced by an isolated red pole, or the positions taken up by a very small freely-suspended soft-iron needle.

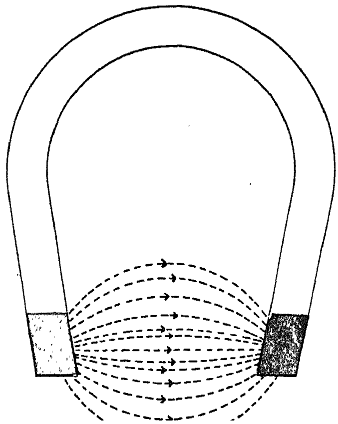


FIGURE 88(b).

Induction. A magnet will induce magnetism in a piece of iron or steel placed in its magnetic field. The lines of force are directed through it and become more intense, as shown in figure 89. The lines of force in the air space near it are thus reduced.

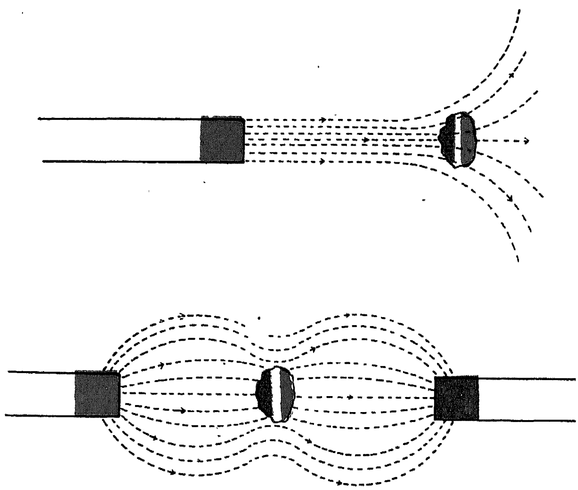


FIGURE 89.

Magnetic Screening. A region shielded by soft iron and steel, as for instance a ship, contains only a small percentage of the lines of force originating from an external source because a large percentage is directed through the surrounding unmagnetised iron, and,

therefore, the directive force due to the Earth's magnetic field at a compass so placed, is reduced.

This effect, shown in figure 90, is specially noticeable at between-deck compasses.

The Effect of Heat and Vibration. Heating iron or steel increases its magnetic properties until a point is reached after which the magnetism is rapidly reduced. Further heating renders the iron non-magnetic. With soft iron this occurs when the iron is red hot.

Vibration assists iron to alter its magnetism, increasing or diminishing it according to circumstances.

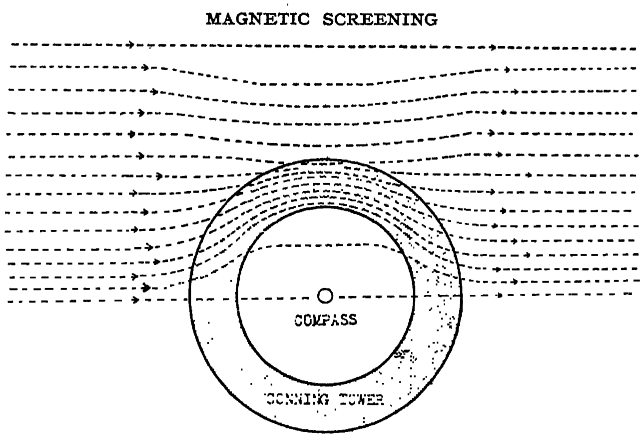


FIGURE 90.

Types of Iron. Iron and steel, when placed in a magnetic field, may be divided into three types according to their reactions to it.

1. *That which is magnetised immediately.* This part is called **Soft Iron** and is said to receive **Induced Magnetism.** On being removed from the magnetic field, soft iron immediately loses this induced magnetism and becomes de-magnetised. Wrought iron is, in general, of this type.

2. *That which is gradually magnetised and remains so when the iron is removed from the magnetic field.* This part is called **Hard Iron** and is said to receive **Permanent Magnetism.** Cobalt steel and tungsten steel are of this type.

3. *That which may act as soft iron or hard iron according to circumstances.* This part is called **Intermediate Iron** and is said to receive **Sub-permanent Magnetism.**

TERRESTRIAL MAGNETISM

Magnetism of the Earth. The Earth is a magnet of irregular shape, and therefore produces lines of force of varying direction and strength. The effect is similar to that which would be caused

if a powerful magnet was placed in the centre of the Earth with its blue end pointing towards Hudson Bay, and its red end towards South Victoria Land, as shown in figure 91. The actual irregularity of the Earth's field can be seen on Chart I at the end of this Chapter.

At each of these places, which are known as the north and south magnetic poles, the lines of force are vertical. Approximately halfway between them, at the magnetic equator, the lines of force are horizontal.

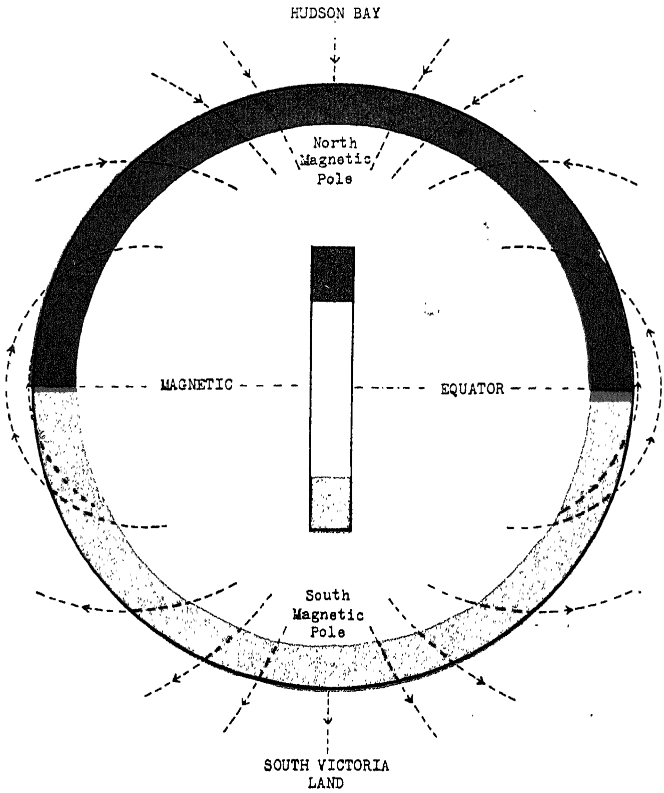


FIGURE 91.

If a compass needle is placed on the Earth's surface it will point with its red end towards the north magnetic pole. For this reason the north magnetic pole is considered to be *blue*, and the south magnetic pole to be *red*. The lines of force flow from south to north. The magnetic equator is thus the dividing line between the blue and red magnetism of the Earth.

Dip. A freely-suspended magnetic needle will set itself in the Earth's lines of force. Figure 91 shows that it will be horizontal at the magnetic equator. In north magnetic latitude it will lie

with its red end pointing down, and in south magnetic latitude with its red end pointing up. The angle between the needle and the horizontal, shown in figure 92, is known as the *angle of dip*, and varies with the magnetic latitude. It is zero at the magnetic equator where the needle lies horizontal, and 90° at the magnetic poles.

Lines joining all places of the same angle of dip are called lines of equal magnetic latitude or *Isoclinal Lines*, and are shown on Admiralty Chart 3598. This chart is reproduced on Chart II at the end of this Chapter.

Intensity of the Earth's Lines of Force. The lines of force are strongest near the magnetic poles, but the greatest horizontal force is felt near the equator. At any point between the magnetic poles

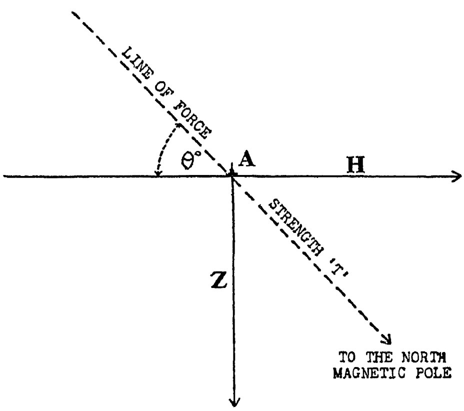


FIGURE 92.

and the magnetic equator, the lines of force can thus be resolved into :

1. a vertical component, called **Z**, shown on Chart III at the end of this Chapter.

2. a horizontal component, called **H**, shown on Admiralty Chart 3603, a reproduction of which is shown on Chart IV at the end of this Chapter.

Since the compass is suspended so that the needles are always horizontal, as described on page 253, it follows that the horizontal component **H** is the directive force on the compass needles, and so it is clear that the magnetic force exerted by the Earth on the compass is greatest near the magnetic equator where **H** has its greatest value. As the magnetic latitude increases **H** decreases and the pointing power of the compass becomes less. In the vicinity of the magnetic poles, **H** becomes so small that the compass is useless.

Suppose that at a place A, shown in figure 92, the line of force,

strength T, is at an angle of dip $\theta°$. Then from the figure it is seen that:

1. the horizontal effect, **H** $= T \cos \theta°$
2. the vertical effect, **Z** $= T \sin \theta°$
3. **Z/H** $= \tan \theta° = \tan$ dip

VARIATION

A magnetic needle freely suspended at any place and acted on by the Earth's magnetic field will set itself in the lines of force at the place, and the semi-great circle of the Earth in the plane of which the needle lies is called the *magnetic meridian* of the place. The horizontal angle between this magnetic meridian and the true meridian of the place is called the *variation*.

Variation is called easterly if the north end of the magnetic meridian is to the east of the true meridian and *vice versa*.

Lines joining places with the same variation are called *Isogonic Lines*, and are shown on Admiralty Chart 2598.

A reproduction of this chart is shown on Chart V at the end of this Chapter.

Changes in Variation. The magnetic poles of the Earth move and change the direction of the lines of force. This change in variation is called *secular* and is marked on the magnetic compass roses on Admiralty charts ; for example :

Variation 16°30′W. (1936) decreasing about 12′ annually.

The variation alters slightly from the normal during the day and during the year. These changes are called *daily* and *annual* changes respectively, and are so small that they are neglected in practical navigation.

Magnetic storms cause large temporary changes in variation. In high latitudes they are usually accompanied by auroræ. The Moon, planets and sunspots may also cause small temporary changes.

PUBLICATIONS SHOWING TERRESTRIAL MAGNETISM

1. *Variation Charts.* These show the variation and the secular change, and the information given is more reliable than that given on the chart roses. Appropriate variation charts are supplied with chart sets.
2. *Charts.* The secular change is marked on the compass roses.
3. *Sailing Directions.* These give the variation and the secular change.
4. *Admiralty Navigation Manual.* Charts I, II, III, IV, and V at the end of this Chapter.

Local Magnetic Disturbance. In certain areas there are magnetic ores and rocks which may cause large local magnetic disturbances.

Information concerning these places, where caution must be exercised, is given in the *Sailing Directions* of the locality. A warning note is given on the charts.

Sunken wrecks may cause local magnetic disturbance.

THE SHIP'S MAGNETISM

The iron and steel used to build a ship is divided magnetically into the three types already described.

1. The hard iron which retains *permanent magnetism.*
2. The soft iron which is magnetised by the Earth's lines of force. This magnetism, which is called *induced magnetism,* depends entirely on the direction in which the ship's head is pointing and the ship's geographical position. If the Earth's lines of force were removed, it would not be retained.
3. The intermediate iron, which retains some of its magnetism for a time. This magnetism is called *sub-permanent magnetism,* and depends on :

(*a*) the direction of the ship's head.
(*b*) the geographical position of the ship at the moment.
(*c*) the past history of the ship's movements and vibrations.

At any moment the compass needle thus feels :

1. the Earth's directive force.
2. the ship's permanent magnetism.
3. the induced magnetism of the ship depending on the direction of her head and her geographical position.
4. the sub-permanent magnetism of the ship caused by the ship's movement from place to place and her vibrations, which are constantly changing quantities.

DEVIATION

The combined effect of the above forces makes the compass needle settle in a direction differing from the magnetic meridian by an angle called the *deviation.*

If the north-seeking end of the compass needle settles to the east of the magnetic meridian, the deviation is said to be easterly and is called positive (+) ; if it settles to the west it is said to be westerly and called negative (—).

THE SHIP'S PERMANENT MAGNETISM

When a ship is building and fitting out, she becomes a combination of permanent magnets, partly on account of the vibration set up by hammering and riveting, and the inclusion of guns, turrets, and heavy steel fittings. A large proportion of this magnetism will alter when the ship first feels the vibration of her machinery and meets heavy seas. A certain proportion, however, always remains and is called the *ship's permanent magnetism.*

It is convenient to consider the effect of the ship's permanent magnetism at a compass position by resolving it into three forces acting at right-angles on the compass needle, as shown in figure 93.

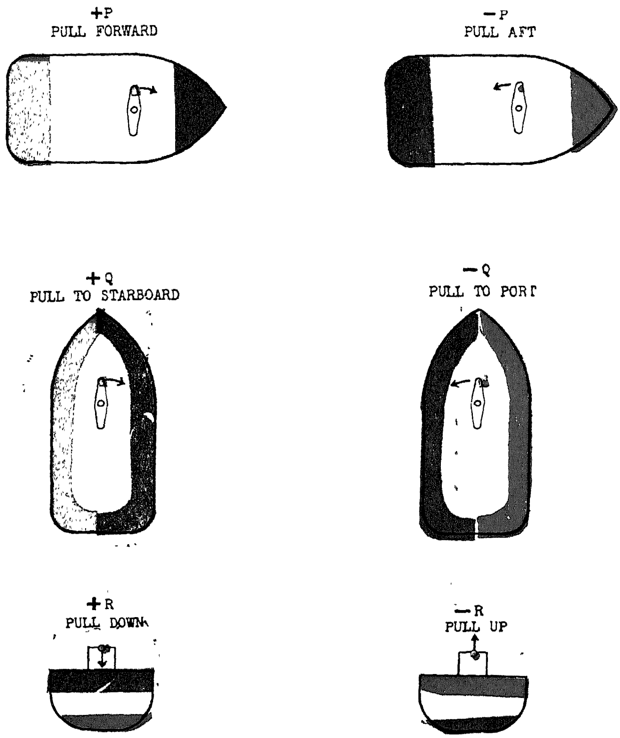


FIGURE 93.

1. **The Fore and Aft Force is called P.** This is termed.

\+ if the red end of the compass needle is pulled *forward*.
— if the red end of the compass needle is pulled *aft*.

2. **The Athwartship Force is called Q.** This is termed:

\+ if the red end of the compass needle is pulled to *starboard*.
— if the red end of the compass needle is pulled to *port*.

3. **The Up and Down Force is called R.** This is termed:

\+ if the red end of the compass needle is pulled *down*.
— if the red end of the compass needle is pulled *up*.

The force **R** does not affect the deviation when the ship is upright, because any upward or downward pull is counteracted by the construction of the compass card, and the card, being pivoted above its centre of gravity, as explained on page 253, resists any force pulling it from the horizontal.

When the ship heels, **R** must be considered. Its effect in these circumstances is discussed later under the heading of *heeling error*.

FORCE P

If a ship has a $-\mathbf{P}$, a pull, that is, aft on the red end of the compass needle, it is seen from figure 94 that:

1. there is no deviation on compass north and south when the pull is in line with the compass needle.
2. there is maximum deviation on compass east and west when the pull is at right-angles to the compass needle.
3. on other directions of the ship's head the deviation varies as the sine of the compass course.

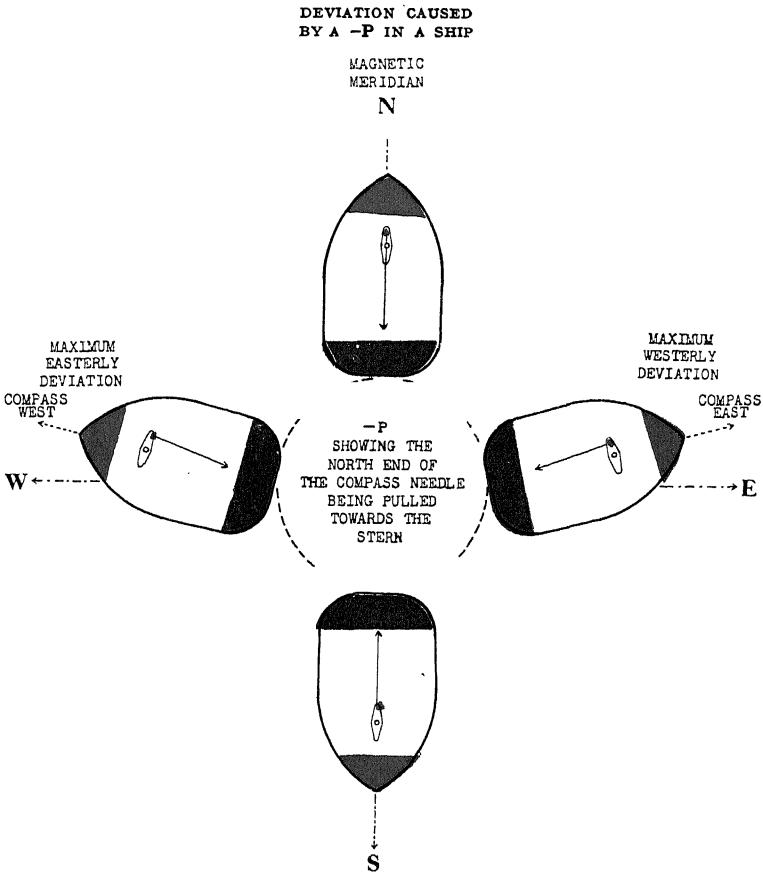


FIGURE 94.

The deviations due to **P** are equal and opposite in opposite semicircles, and are called *semicircular.* Figure 95 shows a typical $-\mathbf{P}$ curve.

Correction. The force **P** is counteracted by fore-and-aft permanent magnets. It is not possible to place these magnets directly under the compass needle because that position is taken up by the

bracket containing the vertical magnets which correct heeling error, to be described later. For this reason the fore-and-aft magnets are placed symmetrically in line on each side, and the final effect of

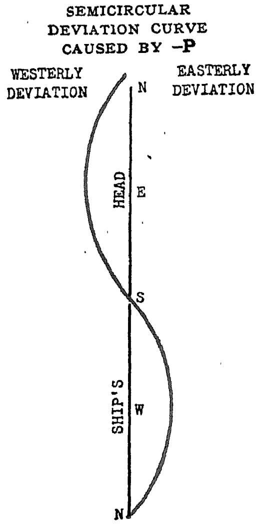


FIGURE 95.

placing them in this way is similar to placing them directly under the compass needle.

Figure 96 shows a ship with a –**P** which is counteracted by fore-and-aft magnets placed with their *red ends aft.*

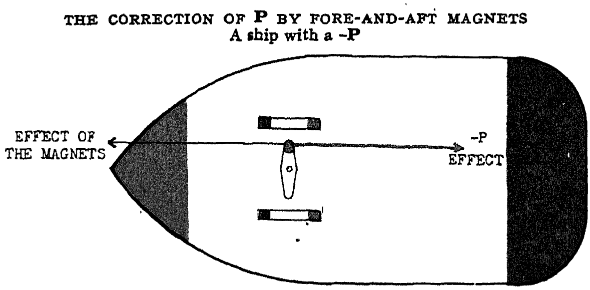


FIGURE 96.

A ship with a +**P** has similar semicircular deviation with opposite signs, and the deviation is corrected by fore-and-aft magnets with their *red ends forward.*

FORCE Q

If a ship has a +**Q**, a pull, that is, to starboard on the red end of the compass needle, it is seen in figure 97 that:

1. there is maximum deviation on compass north and south when the pull is at right-angles to the compass needle.

2. there is no deviation on compass east and west when the pull is in line with the compass needle.

3. on other directions of the ship's head the deviation varies as the cosine of the compass course.

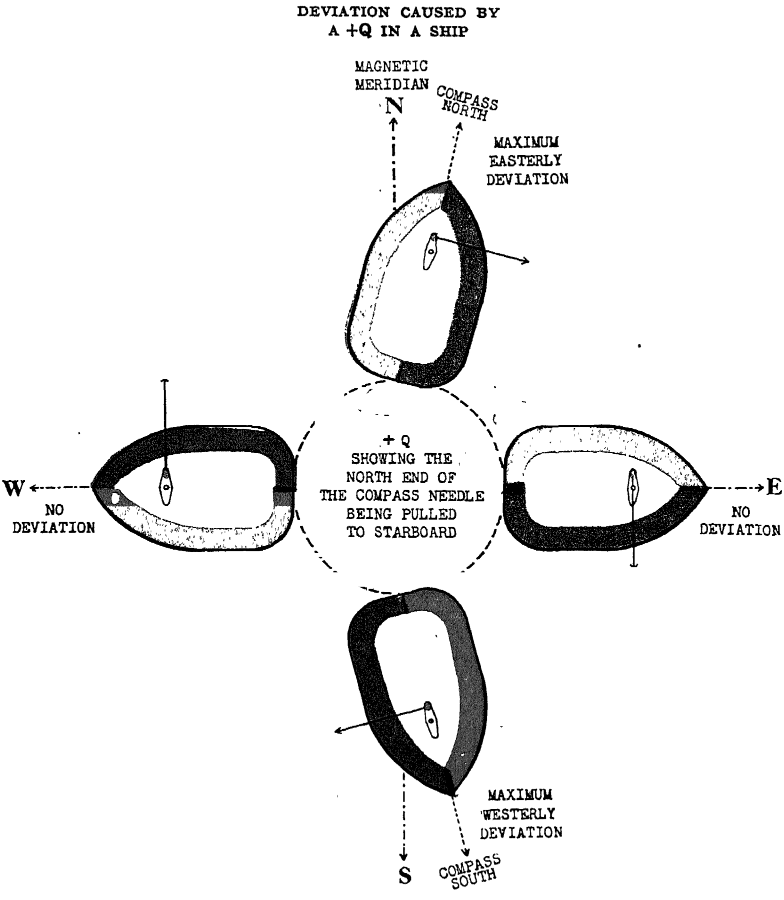


FIGURE 97.

The deviations due to **Q** are equal and opposite in opposite semicircles and are called *semicircular.* Figure 98 shows a typical +**Q** curve.

Correction. Force **Q** is counteracted by athwartship permanent magnets which are placed, usually, abaft the compass needles and always on the opposite side to another corrector, called the Flinders' bar, to prevent induction. Thus in a ship with a +**Q**, athwartship permanent magnets are placed with *red ends to starboard* as shown in figure 99.

A ship with a $-Q$ has similar semicircular deviations with opposite signs, counteracted by placing athwartship magnets *with red ends to port.*

SEMICIRCULAR DEVIATION CURVE CAUSED BY $+Q$

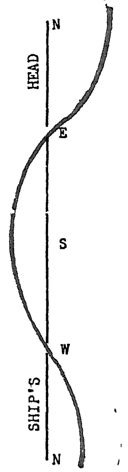


FIGURE 98.

THE CORRECTION OF Q BY ATHWARTSHIP MAGNETS
A ship with a $+Q$

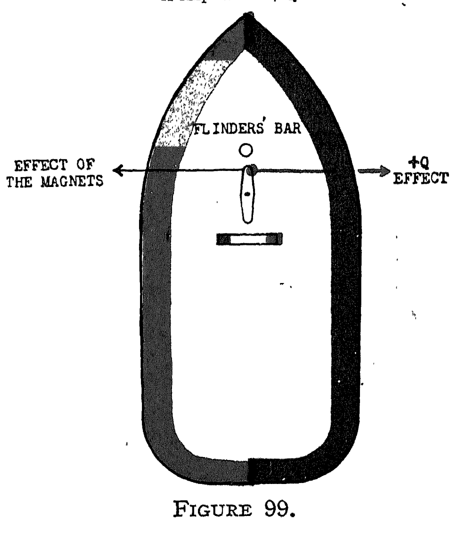


FIGURE 99.

THE EFFECT OF A CHANGE OF MAGNETIC LATITUDE ON THE DEVIATION CAUSED BY FORCES P, Q, AND R

Since the permanent magnetism of a ship remains constant, the above forces also remain constant, but their effect depends on other forces acting on the compass needle. The greatest external

influence is that of the Earth's lines of force. The effect of **P**, **Q**, and **R** therefore alters as the magnetic latitude changes.

Since the compass needle is designed to remain practically horizontal, only the Earth's horizontal force **H** (the directive force of the Earth on the compass needle) need be considered.

If **H** increases (it is greatest at the magnetic equator) the pointing power of the compass needle increases, and the deviation caused by the disturbing effect of **P**, **Q** and **R** decreases. If **H** decreases (it has its least effect at the magnetic poles) the pointing power of the compass needle decreases, and the deviation caused by the disturbing effect of **P**, **Q** and **R** increases. Therefore the effect of **P**, **Q** and **R** varies as 1/**H**.

Details and examples of this variation are given in Volume III.

INDUCED MAGNETISM

The soft iron in a ship can be represented diagrammatically by nine imaginary soft-iron rods having length but no thickness. The accumulative effect of these rods, when they are magnetised by induction, corresponds to the magnetism induced in all the soft iron of the ship by the same inducing force.

Only the four rods representing the inductive effect at a well-placed compass, shown in figure 100, will be considered in this Volume; the remaining rods, and the system on which the signs of the rods are based, are described in Volume III.

Inducing Force. When the ship is upright, fitted with a well-placed compass, the effect of the Earth's horizontal force **H** is represented by two horizontal rods '**a**' and '**e**', and that of the Earth's vertical force **Z** by two vertical rods '**c**' and '**k**'.

When these rods lie in line with the inducing force they are fully magnetised; when at right-angles to it they are not magnetised; at other angles they are only partly magnetised.

'a' ROD

In a ship, the fore-and-aft soft-iron longitudinal frames have magnetism induced in them, and the effect is represented by a '**–a**' rod passing through the compass.

Magnetism of a '–a' Rod. Figure 101 shows that:

1. on north and south the rod is lying in the lines of force of the Earth and is fully magnetised.
2. on east and west the rod is lying at right-angles to the lines of force of the Earth and is not magnetised.
3. on other directions of the ship's head the rod is partly magnetised.

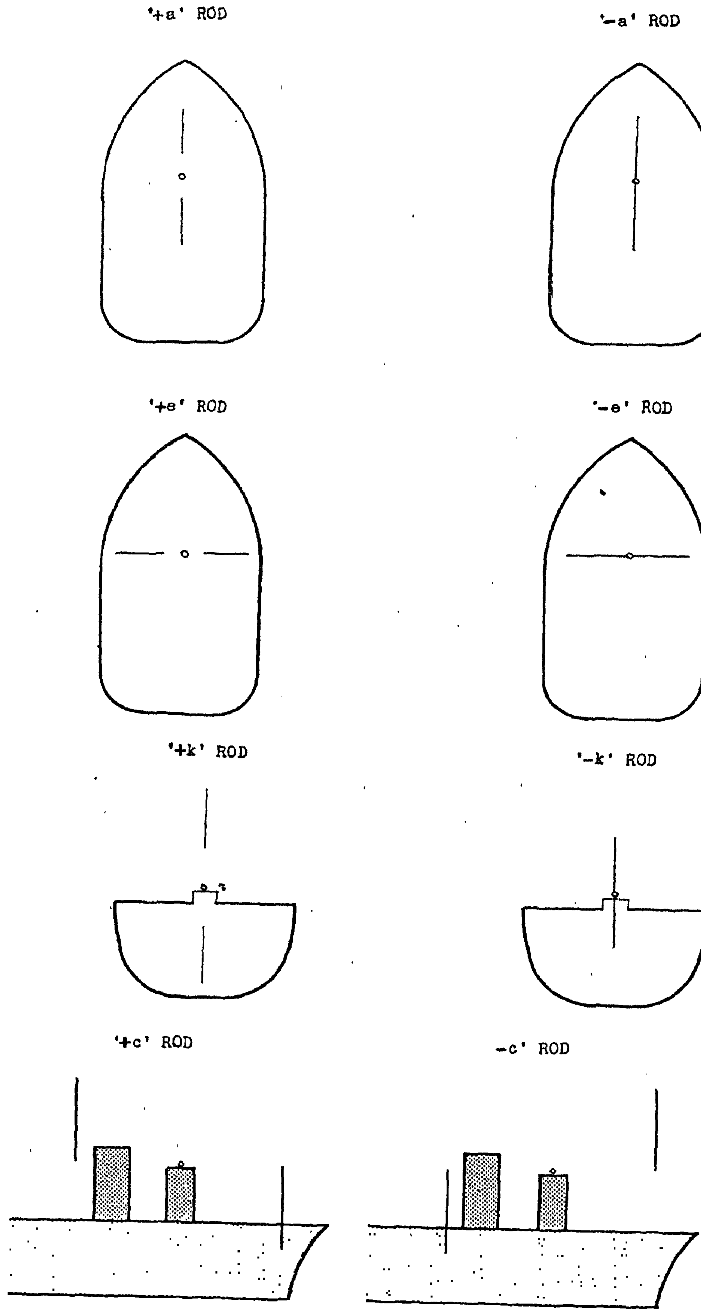


FIGURE 100.

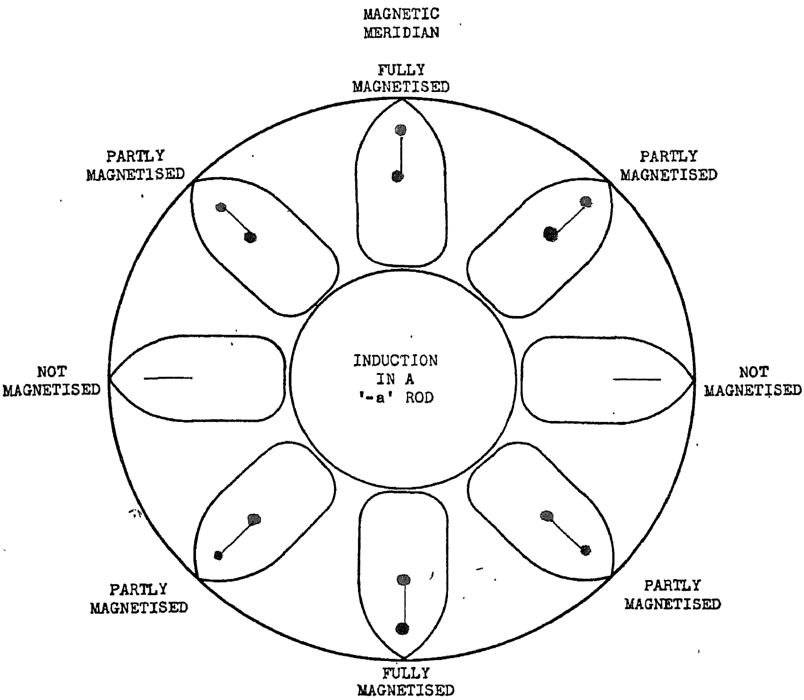


FIGURE 101.

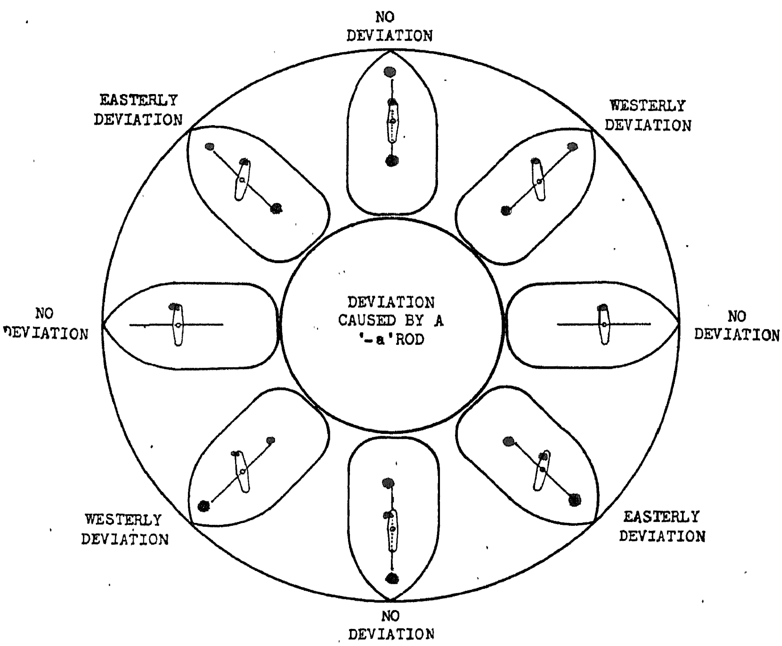


FIGURE 102.

Deviation Due to a '–a' Rod. Figure 102 shows that the deviation is greatest on the quadrantal points, N.E., S.E., S.W., N.W., and nil on the cardinal points, N., S., E., W. The deviation on other directions of the ship's head varies as the sine of twice the compass course.

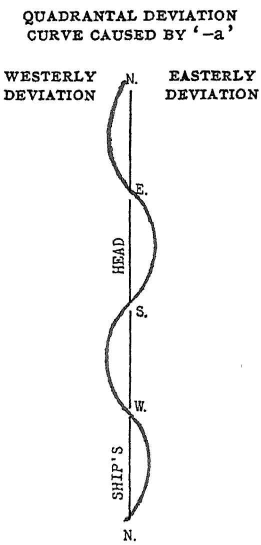


FIGURE 103a.

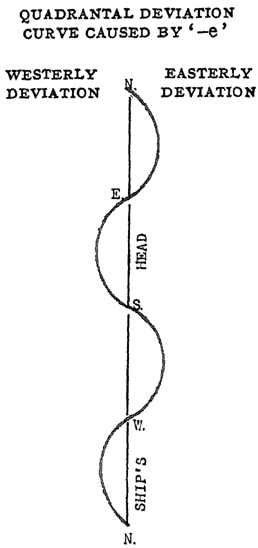


FIGURE 103b.

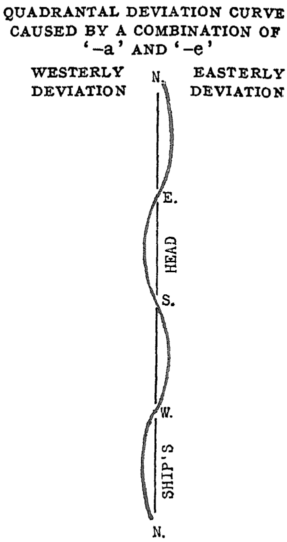


FIGURE 103c.

The deviations are equal and opposite in opposite quadrants, as shown in figure 103a, and are called *quadrantal.*

'e' ROD

In a ship, the horizontal athwartship soft iron beams have magnetism induced in them and the effect is represented by a '–**e**' rod passing through the compass.

Magnetisation of a '–e' Rod. Figure 104 shows that:

1. on east and west the rod is lying in the Earth's lines of force and is fully magnetised.
2. on north and south the rod is lying at right-angles to the Earth's lines of force and is not magnetised.
3. on other directions of the ship's head the rod is partly magnetised.

The Deviation due to a '–e' Rod. Figure 105 shows that the deviation is greatest on the quadrantal points N.E., S.E., S.W., N.W., and nil on the cardinal points N., S., E., W.; on other directions of the ship's head the deviation varies as the sine of twice the compass course.

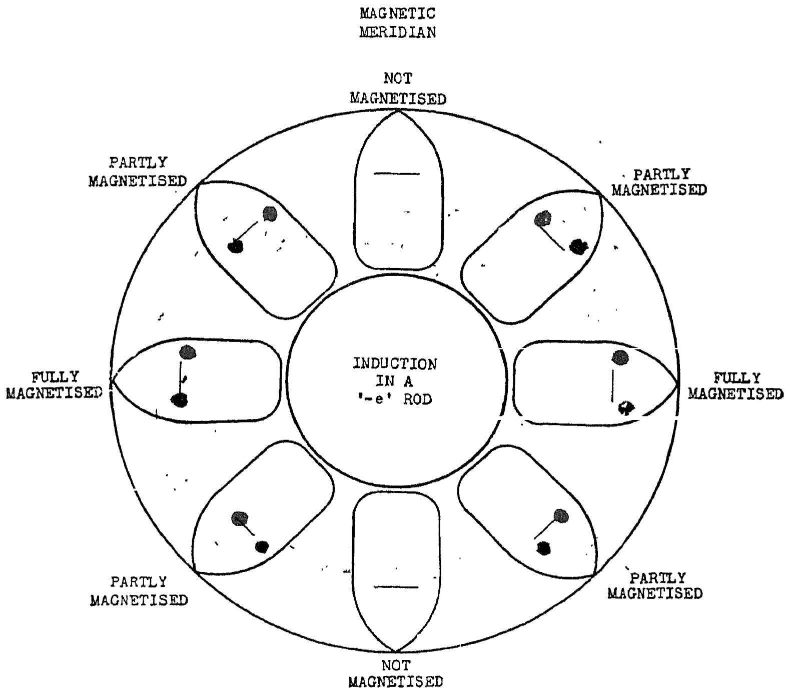


FIGURE 104.

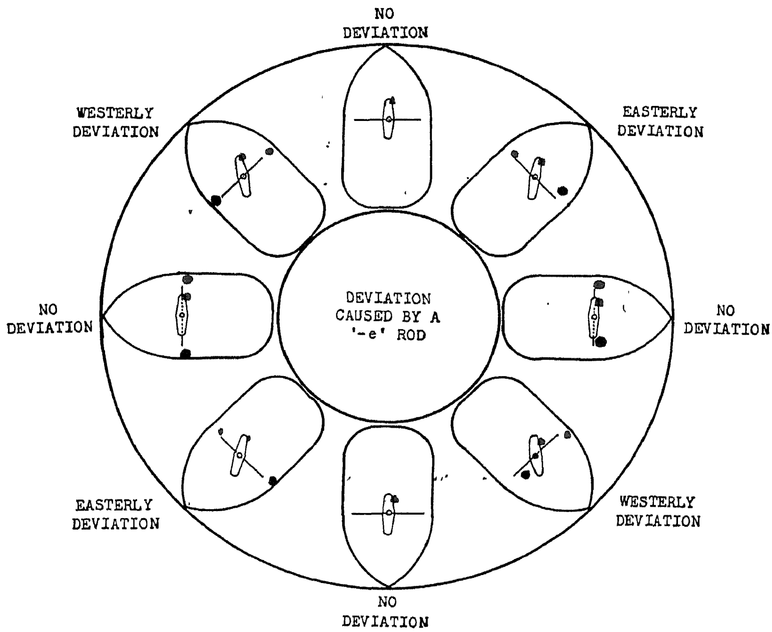


FIGURE 105.

The deviations are equal and opposite in opposite quadrants, as shown in figure 103b, and are called *quadrantal.*

The Correction of the Effect of '–a' and '–e' Rods. Figure 103 shows that the deviation caused by '–**e**' is greater than the deviation caused by '–**a**'; the reason being that the poles of the '–**e**' rod are closer to the compass than the poles of the '–**a**' rod. If, therefore, the deviation curves of the two rods are combined as shown in figure 103c, the resulting curve is that of a smaller '–**e**' rod. This resultant deviation is corrected by soft-iron spheres placed in the athwartship line, which act as '+**e**' rods to counteract the '–**e**' effect.

'c' ROD

The vertical soft iron of a ship has magnetism induced in it by the vertical component of the Earth's lines of force. At a forward compass, which is generally influenced by the vertical soft iron of the funnels, the effect is usually represented by a '–**c**' rod.

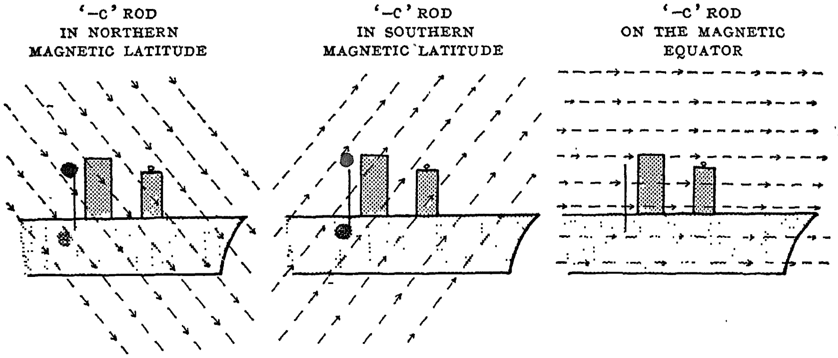


FIGURE 106.

Magnetisation of a '–c' Rod. Figure 106 shows that:

1. in northern magnetic latitude the rod will cause a blue pole abaft the compass.
2. in south magnetic latitude the rod will cause a red pole abaft the compass.
3. on the magnetic equator the rod will not be magnetised because there is no vertical component of the Earth's lines of force.

The magnetism of the '–**c**' rod will thus vary directly as the Earth's vertical force, **Z**, which induces it.

The Deviation due to a '–c' Rod. Figure 107 shows that the deviation is similar to that caused by the force **P** of the ship's permanent magnetism; maximum on east and west, nil on north and south, and varying as the sine of the compass course.

The deviation, being equal and opposite in opposite semicircles, as shown in figure 108, is called *semicircular.*

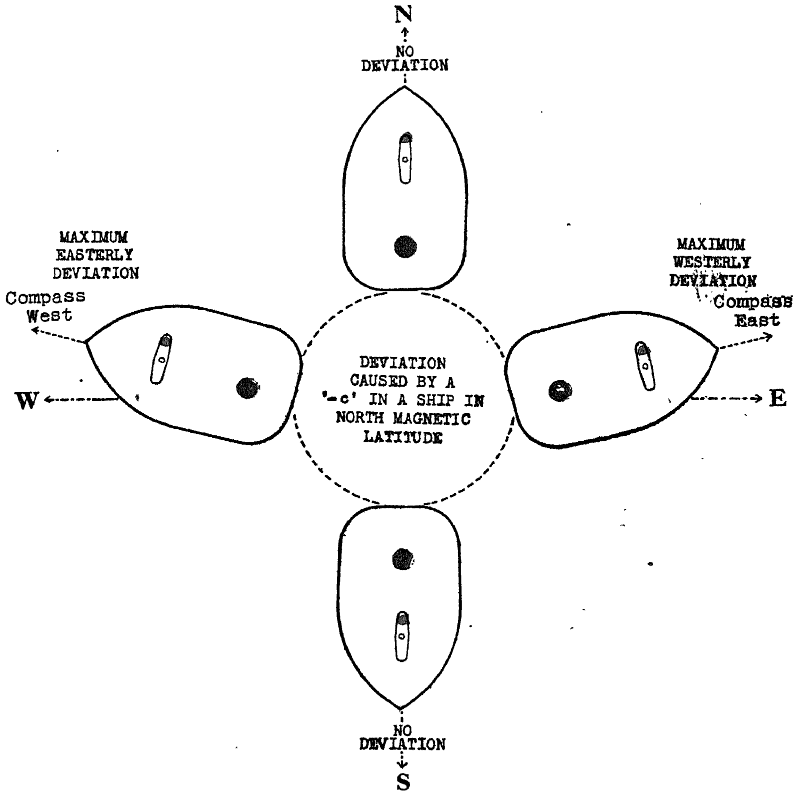


FIGURE 107.

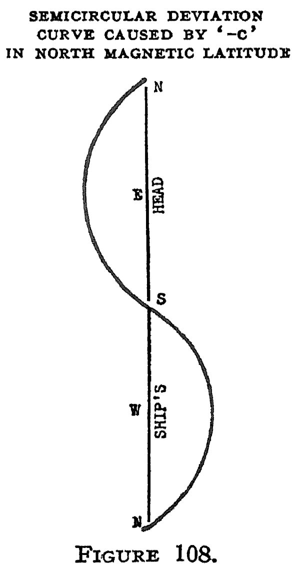


FIGURE 108.

The Correction of the Effect of a '–c' Rod. A bar of soft iron is placed before and below the compass, thus producing an artificial

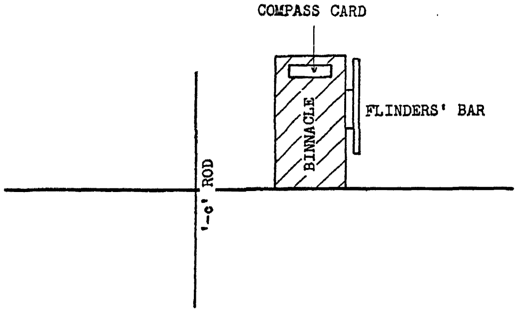


FIGURE 109.

'+**c**' which counteracts the effect of the '–**c**' rod. This bar is called a *Flinders' bar* and is shown in figure 109.

NOTE. The length of Flinders' bar required to counteract '**c**' is taken from Table II on page 264. Before this table is used, however, it is necessary to separate **P** and '**c**' to obtain the value of '**c**'. This is fully explained in Volume III.

'k' ROD

The rod '**k**' does not affect the deviation when the ship is upright: any upward or downward pull is counteracted by the construction of the compass card, as explained on page 253.

When the ship heels, '**k**' must be considered, and this effect will be discussed later under the heading of *heeling error*.

THE EFFECT ON SOFT-IRON RODS WHEN A SHIP CHANGES HER MAGNETIC LATITUDE

The horizontal rods '**a**' and '**e**' are induced by the same force, **H**, which directs the compass needle. As **H** alters on change of magnetic latitude so the strength of the soft-iron rods alters, but since the compass needle is similarly affected by **H**, the effect of the soft-iron rods in deflecting the compass does not change.

Since the vertical rods '**c**' and '**k**' are induced by **Z**, their strength varies directly with the change in **Z**, and their deviation effect inversely with the change in **H**. This is equivalent to **Z**/**H** which is equal to the tangent of the dip.

Details of these variations, with examples, are given in Volume III.

SUB-PERMANENT MAGNETISM

The sub-permanent magnetism of a ship is caused by intermediate iron. The correctors are applied to cancel the deviation found under normal conditions and do not allow for the effects of the intermediate iron under other conditions.

When a ship has been heading in the same direction for a long period and at the same time has been subjected to vibration, as may

occur during a dockyard refit or an ocean passage,the intermediate iron is magnetised and causes deviation when the direction of the ship's head is changed or when the ship alters course. It is, therefore, imperative to check the deviation as often as possible.

When the ship leaves the dockyard, or alters course after a long passage, this magnetism does not immediately disappear: it diminishes with time but while doing so it continues to cause deviation.

When course is altered, the effect at an upper-deck compass is to produce a diminishing deviation towards the original course. This effect is shown in figure 110.

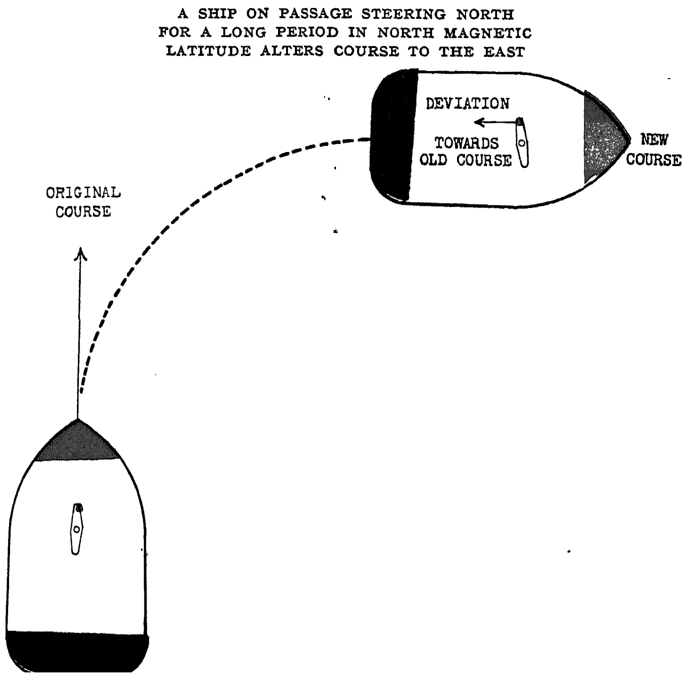


FIGURE 110.

To eliminate errors caused by sub-permanent magnetism when the ship is swung, the rate of swinging should not exceed a complete turn of 360° in approximately 45 minutes.

Sub-permanent magnetism may also be caused by lightning, and the effect may last for several months, altering the deviation on all headings. The effect gradually decreases with time.

This form of magnetism may be expected and the deviation should be checked frequently, when :

1. the ship has been heading in the same direction for a long time.
2. the ship leaves a dockyard after docking or refit.

3. lightning strikes, or passes near to, the ship.
4. heavy gunfiring has been carried out.
5. heavy seas are experienced.

The effect of sub-permanent magnetism is greatest when course is altered from east or west because the sub-permanent athwartship poles are closest to the compass.

CAUSES OF CHANGE IN DEVIATION OR APPARENT DEVIATION

A change of deviation is to be expected when:

1. the ship changes her magnetic latitude.
2. lightning strikes the ship.

A change of deviation may possibly be caused by :

(*a*) the moving of guns, turrets, etc. from their normal positions.
(*b*) leaving tools, etc. near the compass.
(*c*) any alteration of electric leads, or earths on electrical circuits.
(*d*) the moving or installation of electrical instruments.
(*e*) the slipping of stays and guys.
(*f*) the presence of boats alongside the ship, or another ship at a close distance.
(*g*) moving hawser reels.
(*h*) abnormal heating of the funnels.
(*i*) a list on the ship.
(*j*) rust on the corrector magnets or Flinders' bar.
(*k*) induction.
(*l*) sub-permanent magnetism.
(*m*) lightning.
(*n*) magnetic storms.
(*o*) sticky compass card.
(*p*) faulty azimuth mirror.
(*q*) change in magnetic latitude.

SUMMARY OF THE MECHANICAL CORRECTION OF THE DEVIATION

The general principle of correction is the counteracting of the permanent magnetism, felt at the compass, with permanent magnets, and the induced magnetism with soft iron. Thus :

1. forces **P** and **Q** are corrected by fore-and-aft and athwartship permanent magnets respectively.
2. the induced magnetism in '**–a**' and '**–e**' rods is corrected by soft-iron spheres.
3. the induced magnetism in some of the vertical soft iron, represented by '**c**', is corrected by a soft-iron Flinders' bar.

Coefficients. The various causes of deviation are expressed as a trigonometrical function of the compass course. These component causes are grouped together and denoted by letters, called coefficients. A detailed description of all the coefficients is given in Volume III ; the following list takes into account only the forces and soft-iron rods already described.

Group or coefficient A is a fixed deviation on any course.

,, ,, ,, B includes the semicircular deviations caused by **P** and '**c**', which vary as the sine of the compass course.

,, ,, ,, C includes the semicircular deviation caused by **Q**, which varies as the cosine of the compass course.

,, ,, ,, D include the quadrantal deviations caused by '**a**' and '**e**', which vary as the sine of twice the compass course.

Easterly deviation is given the sign +, and westerly deviation is given the sign —.

From the above it can be seen that the deviation on any compass course is:

$$\delta = A + B \sin(\text{compass course}) + C \cos(\text{compass course}) + D \sin(2 \times \text{compass course})$$

ANALYSIS OF THE DEVIATION

When a ship is swung to obtain a deviation table, she is steadied on each of the following points, N., N.E., E., S.E., S., S.W., W., N.W. ; and on each of the headings the deviation is observed and noted.

Accurate correction of each component of the deviation is assisted if the correct value of the deviation is found. This is done by finding the value of the various coefficients from the deviations obtained during the swing.

SUMMARY OF COEFFICIENTS

Coefficient A. Coefficient A is a fixed deviation caused by unsymmetrically-placed soft iron.

It is found by taking the mean of the deviations on equidistant points. Thus, if the deviation on compass north is denoted by N., etc., this mean value is:

$$\tfrac{1}{8}\,[\text{N.} + \text{N.E.} + \text{E.} + \text{S.E.} + \text{S.} + \text{S.W.} + \text{W.} + \text{N.W.}]$$

—and is called + if the algebraic sum of this expression is plus.

It is a constant all-round deviation and cannot be corrected. It can be allowed for at a steering compass, or at a compass not required for taking bearings, by rotating the whole binnacle and thus moving the lubber's line the required amount.

An apparent A is sometimes found when deviation is observed. This may be caused by:

1. using the wrong variation or an incorrect magnetic bearing.
2. a faulty azimuth mirror.
3. the displacement of the lubber line at the steering compass from the ship's fore-and-aft line.

On change of magnetic latitude the deviation due to A does not alter.

Coefficient B. Coefficient B is semicircular deviation caused by the force **P** and the rod '**c**', and varies as the sine of the compass course, from maximum on east and west to nil on north and south.

It is found by taking half the difference between the deviations on east and west—$\frac{1}{2}$ (E.—W.)—and is called + if the algebraic result is plus.

For example: deviation on east, 1°E.; deviation on west, 2°E.

$$\therefore B = \tfrac{1}{2}(1-2) = \tfrac{1}{2} -$$

It is corrected in two parts.

1. The deviation caused by **P** is counteracted by fore-and-aft permanent magnets.
2. The deviation caused by '**c**' is counteracted by Flinders' bar.

P and '**c**', if fully corrected, will not cause any change in deviation on change of magnetic latitude, but this full correction is not always possible, and most ships will find after an appreciable change of magnetic latitude that they have a change in deviation when heading east or west. For this, and other reasons, *every opportunity should be taken to check the deviation.*

Table II on page 264, gives the length of Flinders' bar required to counteract various values of '**c**'. This correction is fully explained in Volume III.

On change of magnetic latitude the deviation caused by uncorrected **P** varies as 1/**H**. The deviation caused by uncorrected '**c**' varies as **Z**/**H**.

Coefficient C. Coefficient C is semicircular deviation caused, mainly, by the force **Q**, and varies as the cosine of the compass course, from maximum on north and south to nil on east and west.

It is found by taking half the difference between the deviations on north and south—$\frac{1}{2}$ (N.—S.)—and is called + if the algebraic result is plus.

For example: deviation on north, 1°W.; deviation on south, 2°W.

$$\therefore C = \tfrac{1}{2}(-1+2) = \tfrac{1}{2} +$$

It is counteracted by athwartship permanent magnets.

On change of magnetic latitude the deviation caused by uncorrected **Q** varies as 1/**H**.

The remarks concerning **P** in the description of coefficient B apply equally to **Q**.

Coefficient D. Coefficient D is quadrantal deviation caused by the rods '**a**' and '**e**' and varies as the sine of twice the compass course, from maximum on N.E., S.E., S.W., and N.W. to nil on N., S., E., and W.

It is found by evaluating the expression:

$$\tfrac{1}{4}\ (\text{N.E.} - \text{S.E.} + \text{S.W.} - \text{N.W.})$$

—and is called + if the algebraic result is plus.

It is counteracted by soft-iron spheres.

If the spheres are in place when the ship is swung and D is found to be +, then the spheres are undercorrecting and will have to be moved in; if D is found to be —, then the spheres will have to be moved out.

Table I on pages 259 to 263 gives the size of the various spheres supplied for different binnacles, and the distances at which they must be placed to correct D.

The distances given are from the centre of the sphere to the centre of the compass.

It is preferable to use large spheres far out from the compass rather than small spheres close in, because this reduces the induction effect explained on page 216.

On change of magnetic latitude the deviation due to D does not change.

Example of Correcting Coefficient D. A ship with a pattern 193 compass has 7-inch spheres in place at 15 inches.

From Table I on page 259 it is seen that the spheres in their present position correct a coefficient D of 2°34′.

During a swing the following deviations are found:

Ships head by compass	*Deviation*
N.E.	5°E.
S.E.	1°E.
S.W.	1°E.
N.W.	3°W.

From the above observations a value of uncorrected coefficient D can be found, thus:

$$\text{uncorrected coefficient D} = \tfrac{1}{4}\ (5 - 1 + 1 + 3) = 2 +$$

To find the coefficient D of the ship, this uncorrected value must be added or subtracted, according to the sign, to the value of D already corrected by the spheres in their present position. Thus:

coefficient D already corrected by spheres	=	2°34′	
,, ,, found from the swing	=	2°	+
,, ,, of the ship	=	4°34′	

From Table I it is clear that the spheres must be moved in to $12\frac{3}{4}$ inches.

TABLE OF COEFFICIENTS

Coefficient	*Caused by :*	*Found by taking the mean of the deviations on :*	*Sign*	*Corrected by :*	*Change when the ship alters her magnetic latitude*	*Type of deviation*
A	Unsymmetrical soft iron.	8 or 16 equidistant headings.	+			Constant
B	(i) **P** (ii) '**c**'	East and west, and changing the sign on west.	if the algebraic sum	(i) Fore-and-aft permanent magnets. (ii) Flinders' bar	(i) $\propto$ 1/**H** (ii) $\propto$ **Z**/**H**	Semi-circular
C	**Q**	North and south, and changing the sign on south.	of column	Athwartship permanent magnets.	$\propto$ 1/**H**	Semi-circular
D	Excess of '−**e**' over '−**a**'.	Quadrantal points, and changing the signs on S.E. and N.W.	III is plus	Spheres	No change	Quadrantal

HEELING ERROR

When a ship is upright, the vertical pulls of the permanent, induced, and sub-permanent magnetism of a ship cause no deviation, but as soon as she moves from the upright they cause horizontal pulls and consequent deviation.

At a well-placed compass, when the ship is heeled, the needles feel the effects of the force **R** and the rods '**c**' and '**k**' together with an effect of uncorrected '**e**' rod. The resulting deviation is called heeling error.

The Effect of the Force R. When a ship moves from the upright, the pull becomes partly horizontal and causes a deviation. When the ship rolls and pitches, the pull varies from side to side producing an oscillation of the compass.

It is usual for a ship built in north magnetic latitude to have a +**R**, and figure 111 shows a ship so built, listing to starboard and to port. In both situations it can be seen that the deviation caused is *towards the high side.*

HEELING ERROR CAUSED BY +R

FIGURE 111.

The Effect of a 'k' Rod. In a ship there is seldom any vertical soft iron above the standard compass. For this reason it is usual to to find a '+**k**'.

The '**k**' rod is induced by the Earth's vertical force **Z** and produces similar pulls to the force **R**. As the Earth's vertical force changes with magnetic latitude so also the effect of '**k**' changes. In north magnetic latitude it produces a pull similar to +**R**. On the magnetic equator where the Earth's vertical force **Z** is nil, it will not be induced and so produces no effect. In south magnetic latitude it produces a pull to oppose +**R**. This effect is shown in figure 112.

The Effect of Uncorrected 'a' and 'e' Rods. The spheres correct only the difference in the deviations caused by these rods, and there remains the parts of the '**a**' and '**e**' rods, the effect of which is equal and opposite and therefore negligible only when the ship is upright. When the ship moves from the upright these uncorrected rods are induced by **Z** and cause further deviation.

This effect is shown in figure 113.

The Correction of Heeling Error. It is not possible to correct the induced and the permanent magnetism separately, and the

complete correction is made by vertical permanent magnets, placed in a bucket under the compass needles.

The method of correcting heeling error with the ship upright, by means of the heeling error instrument, is explained in Volume III.

On changing the magnetic latitude, **Z** alters and the induced magnetism alters so that the vertical magnets already in place

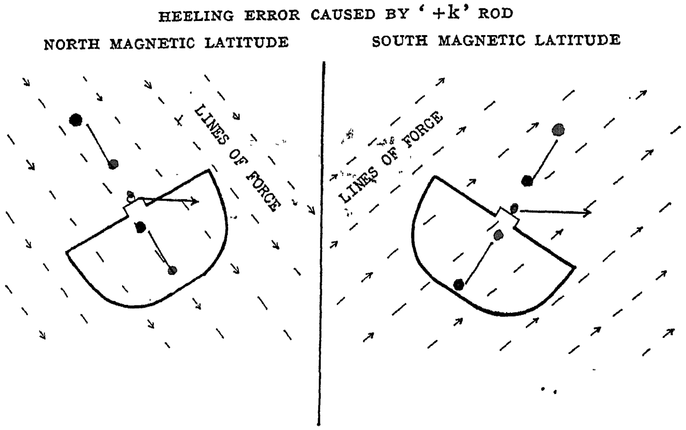


FIGURE 112.

either over correct or under correct this change. The change becomes apparent in a seaway by the movement of the compass card. To discover if heeling error exists, take a bearing of an object when the ship is rolling or pitching. If there is heeling error, the compass card will move either side of the bearing.

Sometimes the inadvertent yawing of the ship's head gives rise to an apparent heeling error.

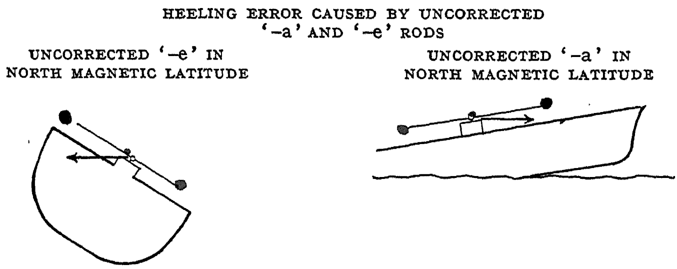


FIGURE 113.

Heeling error can be corrected at sea by taking a bearing of an object with the ship's head north or south and then raising or lowering, or altering, the number of the vertical magnets until the bearing remains steady throughout the roll or pitch.

Owing to induction between the vertical magnets and the Flinders' bar, the deviation due to coefficient B will alter, and it will

be necessary to check the deviation table as soon as possible. For this reason, when heeling error is found to exist when at sea, only the steering compass should be corrected because *no correctors at a standard compass should be moved unless the ship is swung immediately afterwards.*

SWINGING SHIP

A representative of the Admiralty compass department will swing ship and adjust compasses :

1. before the preliminary trial of a new ship.
2. after any extensive structural alterations on or near the bridge or compass position.

At other times the ship should be swung, if possible, by a qualified navigating officer. Officers are appointed for this duty at home ports.

When a navigating officer is not available, the correctors are not to be altered before obtaining the permission of the Commanding Officer.

Ships should be swung :

(*a*) as above.
(*b*) at least once every year.
(*c*) after changing any correctors.
(*d*) on change of magnetic latitude.

All deviations obtained should be written in the navigating officer's note book, and the deviation table from every swing should be tabled in the *Navigational Data Book.*

Precautions to be Taken before Swinging Ship. Always note the following points :

1. The funnels should be at their normal seagoing temperature.
2. The ship should be upright so that there is no heeling error.
3. The compass should be tested for friction.
4. The lubber's line should be checked to make certain that it is in, or parallel to, the fore-and-aft line of the ship.

The lubber's line can be checked by taking a bearing of the stem or the jackstaff with the azimuth mirror ; the lubber's line should then appear to be in transit. Another method is to place plumb lines before and abaft the compass.

5. The accuracy of the azimuth mirror. Instructions for this procedure are given in the lid of the azimuth-mirror stowage box.
6. All movable iron, for instance davits, catapults and guns, should be in the normal sea position.
7. No ship should be within three cables as she may cause magnetic effects.

METHODS OF SWINGING SHIP

By Reciprocal Bearings. In various places there are magnetic huts containing a verge plate set up in the magnetic meridian. A

party is sent ashore and, at a pre-arranged signal, takes a bearing of the ship by verge plate, while the ship observes the bearing of the hut. The verge-plate bearing is then signalled to the ship. If there is no magnetic hut this procedure can be carried out by a party sent ashore with a landing compass.

A system of signalling between the ship and shore party should be arranged, as for instance :

flag close up—*stand by*
flag dipped —*observe*

An example of a completed form S 374a for a swing by reciprocal bearings is given on pages 250 and 251.

By Bearing of a Distant Object. This method requires the ship's position to be known or fixed, and the magnetic bearing of the distant object is then obtained from the chart. Some charts give lines of bearing to distant objects.

The ship must be swung in as small a circle as possible and the following rules for safe distances should be noted.

If the ship is :

1. at a buoy, the distance of the object should be not less than 4 miles.

2. at single anchor, the distance of the object should be not less than 6 miles.

3. under way, the distance of the object should be not less than 10 miles, and the ship must not alter her position by more than 160 yards. (160 yards at 10 miles subtends an angle of about half a degree.)

In the above circumstances the same magnetic bearing will suffice for all directions of the ship's head.

The ship should always be as close as possible to the buoy or anchor, and if under way, she should turn by working her engines ahead and astern.

If, with bad visibility, it is necessary to use objects closer than the above distances, the change in magnetic bearings caused by the varying position of the compass, must be allowed for.

By Transits. In well-charted anchorages and ports where there are many conspicuous charted objects, it may be possible to swing on transits.

By Azimuths of a Heavenly Body. The Sun, at rising and setting, is a suitable object for easy observation. The true bearing is taken from *Weir's Diagram* or azimuth tables, or is worked out.

An example of a completed form S 374a for a swing by azimuths of a heavenly body is given on pages 248 and 249.

By Gyro Compass. This is a useful method for placing correctors. The accuracy of a deviation table obtained by this method is dependent upon the accuracy of the gyro compass, and the results of

a swing should therefore be checked at the first opportunity by one of the above methods.

Between-Deck Compasses. By a suitable signalling arrangement of voice pipes, bells, or sirens, the direction of the ship's head at the between-deck compass is observed at the same time that observations are made at the standard compass. The direction of the ship's head by standard compass is noted when the observations are made, and when the deviation of the standard compass has been found, it is a simple matter of comparison to find the deviations of the between-deck compass. An example of finding the deviations of a between-deck compass on form S 374a is given on pages 248 and 249.

NORMAL PROCEDURE FOR SWINGING SHIP

Before Swinging Ship. Check the positions of the correctors from the previous records in the *Navigational Data Book* and work out from Table I on pages 259 to 263 the amount of coefficient D that the spheres are correcting in their present position. (Coefficient D is already corrected.)

On Arriving at the Position Chosen for Swinging Ship

1. Steady the ship on each of the quadrantal points, N.E., S.E., S.W., and N.W., and find the deviations. From these deviations work out a value of the uncorrected coefficient D, and apply this result to the value of D already corrected by the spheres in their present position. This should be worked out before sailing. Look up this new value of D in Table I and re-set the spheres. The distance given is from the centre of the sphere to the centre of the compass card.
2. Steady the ship on a cardinal point, N., S., E., or W. Insert corrector magnets if necessary; otherwise raise or lower those already in place, and take out all deviation. Remember the corrector magnets that have to be altered are those at right angles to the compass needle.
3. Steady the ship on the next cardinal point. Take out all deviation with the other set of corrector magnets.
4. As there may be a coefficient A, repeat the above procedure on the other cardinal points and take out *half* of any deviation found.
5. Steady the ship on all points and obtain the deviation tables.

CORRECTING A WELL-PLACED COMPASS BY SWINGING THE SHIP BY BEARINGS OF THE SUN

A pattern 193 compass has the following correctors in place: 6 inch spheres at 12 inches. (Centre of the sphere to the centre of the compass.) Fore-and-aft permanent magnets, red ends forward. Athwartship permanent magnets, red ends to starboard.

The ship is swung on the Sun and the following results are obtained :

Ship's head by standard compass	*Sun's true bearing*	*Sun's compass bearing*
N.	085°	N.82°E.
N.E.	085°	N.84°E.
E.	086°	N.84°E.
S.E.	086½°	N.82½°E.
S.	087°	N.82°E.
S.W.	087°	N.81½°E.
W.	087½°	N.80½°E.
N.W.	088°	N.83½°E.

It is first necessary to find the deviation and therefore the variation must be known. From the chart this is found to be 4°E.

Proceeding :

Ship's head by standard compass	*Sun's true bearing*	*Sun's magnetic bearing*	*Sun's compass bearing*	*Deviation*
N.	085°	N.81°E.	N.82°E.	1°W.
N.E.	085°	N.81°E.	N.84°E.	3°W.
E.	086°	N.82°E.	N.84°E.	2°W.
S.E.	086½°	N.82½°E.	N.82½°E.	nil
S.	087°	N.83°E.	N.82°E.	1°E.
S.W.	087°	N.83°E.	N.81½°E.	1½°E.
W.	087½°	N.83½°E.	N.80½°E.	3°E.
N.W.	088°	N.84°E.	N.83½°E.	½°E.

It is now possible to find the approximate coefficients.

$$\text{Coefficient A} = \frac{-1-3-2+1+1\frac{1}{2}+3+\frac{1}{2}}{8} = 0$$

$$\text{Coefficient B} = \frac{-2-3}{2} = 2\tfrac{1}{2}\,-$$

$$\text{Coefficient C} = -1-1 = 1\,-$$

$$\text{Coefficient D} = \frac{-3+1\frac{1}{2}-\frac{1}{2}}{4} = \tfrac{1}{2}\,-$$

If it is decided to take out the deviations, the correctors will have to be moved as follows :

Coefficient B. Reduce the number of fore-and-aft magnets with their red ends forward. It may be necessary to remove all of them and insert magnets with their blue ends forward.

Coefficient C. Reduce the number of athwartship magnets with their red ends to starboard. Here again, it may be necessary to remove all of them and insert magnets with their blue ends to starboard.

Coefficient D. The spheres in their present position are already correcting a value of coefficient D, and to find the true value of D it is necessary to add or subtract the amount found from the swing to the value which is already corrected.

From Table I on page 259:

6″ spheres at 12″ correct	2°56′
uncorrected D found from the swing	30′ —
coefficient D of the ship	2°26′

To correct this new value of D, it is necessary to move the spheres to 12·65 inches.

NOTE. If any of the correctors are moved, it will be necessary to carry out a further swing to find the new values of the coefficients.

FINDING THE DEVIATIONS OF THE STEERING COMPASS

Suppose, in the above example, the direction of the ship's head by steering compass during the swing was found to be as follows:

Ship's head by standard compass	*Ship's head by steering compass*
N.	N.1°W.
N.E.	N.40°E.
E.	N.84°E.
S.E.	S.47°E.
S.	S.2°W.
S.W.	S.49½°W.
W.	N.84°W.
N.W.	N.43½°W.

To find the deviations:

Ship's head by standard compass	*Deviation of standard compass*	*Magnetic direction of ship's head*	*Ship's head by steering compass*	*Deviation the steerin compass*
N.	1°W.	N.1°W.	N.1°W.	nil
N.E.	3°W.	N.42°E.	N.40°E.	2°E.
E.	2°W.	N.88°E.	N.84°E.	4°E.
S.E.	nil	S.45°E.	S.47°E.	2°E.
S.	1°E.	S.1°W.	S.2°W.	1°W.
S.W.	1½°E.	S.46½°W.	S.49½°W.	3°W.
W.	3°E.	N.87°W.	N.84°W.	3°W.
N.W.	½°E.	N.44½°W.	N.43½°W.	1°W.

EXAMPLE OF A SWING BY BEARINGS OF A HEAVENLY BODY

S.—374a. (Revised—February, 1934.) **RECORD OF OBSERVATIONS FOR DEVIATION**

To be transmitted to The Director, Compass Dept., Slough, Bucks., annually, on December 31st, also after acceptance trials and after large structural alteration in vicinity of Bridge.

Date of Swing, 7th March, 1935. Captain, A.B.C. Place of Observation, Greenock. H.M.S. 'Dryad'

Description of Ship, Convoy Sloop. Nav. Officer., X.Y.Z. Latitude 56°00′ N. Longitude 4° 45′ W. Direction of Swing, clockwise.

Time by watch	Direction of Ship's Head by Standard Compass	Bearing of* Sun: By Standard Compass	Bearing of* Sun: Magnetic (or reciprocal bearing)	Deviation of Standard Compass Patt. No. 195	Comparison of Steering Compasses with Standard: Ship's Head by Compass Patt. No. 195	Deviation of Compass	Ship's Head by Compass Patt. No.	Deviation of Compass	Ship's Head by Compass Patt. No.	Deviation of Compass
1157	North	S.15¾°W.	S.14¼°W.	1½° W.	N.½°W.	1° W.				
1201	N.N.E.	S.17¼°W.	S.15¼°W.	2° W.	N.21°E.	½° W.				
1203	N.E.	S.16°W.	S.15¾°W.	¼° W.	N.45°E.	¼° W.				
1206	E.N.E.	S.16¼°W.	S.16¾°W.	½° E.	N.68°E.	nil				
1208	East	S.17¾°W.	S.17¼°W.	½° W.	S.89½°E.	1° W.				
1211	E.S.E.	S.20½°W.	S.18¼°W.	2¼° W.	S.68°E.	1¾° W.				
1216	S.E.	S.21½°W.	S.19½°W.	2° W.	S.46¾°E.	¼° W.				
1218	S.S.E.	S.21°W.	S.20°W.	1° W.	S.24°E.	½° E.				
1131	South	S.6¾°W.	S.7°W.	¼° E.	South	¼° E.				
1134	S.S.W.	S.6½°W.	S.7¾°W.	1¼° E.	S.24½°W.	¾° W.				
1137	S.W.	S.6½°W.	S.8½°W.	2° E.	S.47½°W.	½° W.				
1138	W.S.W.	S.6¼°W.	S.8¾°W.	2½° E.	S.69°W.	1° E.				
1144	West	S.10½°W.	S.10½°W.	nil	N.89¼°W.	¾° W.				
1146	W.N.W.	S.12°W.	S.11°W.	1° W.	N.68°W.	½° W.				
1151	N.W.	S.13½°W.	S.12½°W.	1° W.	N.46°W.	nil				
1154	N.N.W.	S.13°W.	S.13¼°W.	¼° E.	N.23°W.	¾° E.				

When Sun has been used—Error of watch on ship, apparent time, Correct. Variation allowed, 15°W.

When distant Object has been used—Name........distance........ Total time for swing 50 mins.

*Insert here which method has been employed, " Sun," " Distant Object," or " Shore Compass."

Swinging Officer, X.Y.Z.

Rank, Lieutenant (N).

Approved, A.B.C.
Captain.

DESCRIPTION AND POSITION OF CORRECTORS

Compass	Spheres		Flinders' Bar	Horizontal Magnets		Vertical Magnets
	Size	Distance Centre of Compass to Centre of Sphere	Length, Diameter and Position of	Fore and aft Size, Number, Position and Direction	Athwartships Size, Number, Position and Direction	Number, Size, Height and Direction
Standard	6″	10″	$15\frac{3}{4}$″ × 3″ Forward side of the compass.	8″ × $\frac{3}{8}$″ : 2 at 4 Red aft	8″ × $\frac{3}{8}$″ : 2 at 2 8″ × ″ : 1 at 3 Red to starboard.	9″ × $\frac{3}{8}$″ 2 at 18 Red up
Steering	9″	$10\frac{1}{4}$″	$8\frac{1}{4}$″ × 3″ Forward side of the compass.	8″ × $\frac{3}{8}$″ : 1 at 3 8″ × $\frac{3}{8}$″ : 1 at 4 8″ × $\frac{3}{16}$″ : 1 at 1 8″ × $\frac{3}{16}$″ : 1 at 2 Red aft	8″ × $\frac{3}{8}$″ : 2 at 2 8″ × $\frac{3}{8}$″ : 2 at 6 8″ × $\frac{3}{16}$″ : 1 at 3 Red to starboard.	Nil
L.C.T.						
After						

APPROXIMATE COEFFICIENTS

Compass	A	B	C	D	E	
Standard	0·3 −	0·3 −	0·9 −	1·2 +	0·2 −	
Steering	0·3 −	0·1 −	0·6 −	0·1 −	0·3 +	
L.C.T.						
After						

Date of previous swing, First swing.
Has the position of correctors at the standard compass been altered since last swing ?.................

REMARKS :—

(To include any observations made since the previous swing on the effect on the compasses of training turrets, etc. ; also full details of any alterations which have been made in the arrangement or proximity of magnetic material or electric fittings in the vicinity of any compass giving distances.)

EXAMPLE OF A SWING BY RECIPROCAL BEARINGS

S.—374a. (Revised—February, 1934) **RECORD OF OBSERVATIONS FOR DEVIATION**

To be transmitted to The Director, Compass Dept., Slough, Bucks., annually, on December 31st, also after acceptance trials and after large structural alteration in vicinity of Bridge.

Date of Swing, 1st May, 1935. Captain, A.B.C. Place of Observation, Spithead. H.M.S. 'Dryad'

Description of Ship, Sloop. Nav. Lieutenant, X.Y.Z. Latitude 50° 45′ N. Longitude 1° 10′ W. Direction of Swing, clockwise.

Time by Watch	Direction of Ship's Head by Standard Compass	Bearing of * Shore Compass		Deviation of Standard Compass Patt. No. 195		Comparison of Steering Compasses with Standard					
		By Standard Compass	Magnetic (or reciprocal bearing)			Ship's Head by Compass Patt. No.	Deviation of Compass	Ship's Head by Compass Patt. No.	Deviation of Compass	Ship's Head by Compass Patt. No.	Deviation of Compass
1445	North	N.73½°E.	N.72°E.	1½°	W.						
1448	N.N.E.	N.81°E.	N.79½°E.	1½°	W.						
1453	N.E.	N.87°E.	N.85°E.	2°	W.						
1502	E.N.E.	N.52½°E.	N.52¾°E.	¼°	E.						
1507	East	N.40½°E.	N.41°E.	½°	E.						
1510	E.S.E.	N.19°E.	N.20°E.	1°	E.						
1514	S.E.	N.3°W.	N.2½°W.	½°	E.						
1517	S.S.E.	N.9°W.	N.8°W.	1°	E.						
1526	South	N.26°W.	N.25½°W.	½°	E.						
1531	S.S.W.	N.21°W.	N.21°W.	nil							
1422	S.W.	N.14°E.	N.14½°E.	½°	E.						
1425	W.S.W.	N.20°E.	N.21°E.	1°	E.						
1427	West	N.29°E.	N.29°E.	nil							
1432	W.N.W.	N.40°E.	N.39°E.	1°	W.						
1437	N.W.	N.50°E.	N.49¾°E.	¼°	W.						
1441	N.N.W.	N.60½°E.	N.60°E.	½°	W.						

When Sun has been used—Error of watch on ship, apparent time........ Variation allowed, 11¾°W.

Swinging Officer, X.Y.Z.

When distant Object has been used—Name..........distance.......... Total time for swing 69 mins.

Rank, Lieutenant (N)

*Insert here which method has been employed, "Sun," "Distant Object," or "Shore Compass."

Approved, A.B.C.
Captain

DESCRIPTION AND POSITION OF CORRECTORS

Compass	Spheres		Flinders' Bar	Horizontal Magnets		Vertical Magnets
				Fore and Aft	Athwartships	
	Size	Distance Centre of Compass to Centre of Sphere	Length, Diameter and Position of	Size, Number, Position and Direction	Size, Number, Position and Direction	Number, Size, Height and Direction
Standard	6″	10″	$15\frac{3}{4}''\times 3''$ Forward side of the compass.	$8''\times\frac{3}{8}''$: 2 at 4 Red aft	$8''\times\frac{3}{8}''$: 2 at 2 $8''\times\frac{3}{16}''$: 1 at 3 Red to starboard.	$9''\times\frac{3}{8}''$ 2 at 18 Red up
Steering						
L.C.T.						
After						

APPROXIMATE COEFFICIENTS

Compass	A	B	C	D	E	
Standard	0·09 −	0·25 +	1·00 −	0·44 −	0·38 −	
Steering						
L.C.T.						
After						

Date of previous swing, 7th March, 1935

Has the position of correctors at the standard compass been altered since last swing ? No.

REMARKS :—

(To include any observations made since the previous swing on the effect on the compasses of training turrets, etc. ; also full details of any alterations which have been made in the arrangement or proximity of magnetic material or electric fittings in the vicinity of any compass giving distances.)

NOTE. Lewis guns have been fitted 15 feet from the standard compass.

FORM S 374a

This form is supplied for the purpose of keeping a record of the deviations of all compasses in service, and to simplify the working when the ship is swung.

It should be used whenever a ship is swung to find the deviation, and a copy is to be sent to the Director of the Compass Department, Slough.

COMPASSES AND BINNACLES

The following compasses and binnacles are used in H.M. ships.

Fleet Type. Used in cruisers and ships larger than cruisers. Compass pattern 193, in binnacle pattern 194.

NOTE. This type is being replaced, in all surface ships, by the 'flotilla' type. A number of pattern 22A compasses and pattern 44A binnacles are still in service.

Flotilla Type. Used in destroyers and sloops. Compass pattern 195, in binnacle pattern 196.

NOTE. This type is being fitted to all surface ships (1938). A number of pattern 173 compasses and pattern 172 binnacles are still in service.

Submarine Type. Compass pattern 188, in binnacle pattern 189. Projector compass pattern 28P, in R.L. type binnacle. A number of pattern 184 compasses and pattern 185 binnacles are still in service.

Trawlers. Steering compass pattern 921, in overhead binnacle pattern 922.

Boat Compasses. Fast motor boats—compass pattern 1133.
All other boats—compass pattern 183.

Binnacles in Hand-Wheel Positions. Binnacle pattern 1830 is used with compass pattern 183 in the hand-wheel positions of sloops, etc.

Emergency Steering Pointers. These instruments work on the gyroscopic principle and are supplied to ships when it is not possible to use a magnetic compass in the lower steering position.

Dry Compasses. Dry compasses are liable to be disturbed by a slight tilting of the compass bowl, gunfire, etc. They are still used in the Merchant Navy but are being superseded by liquid compasses.

Gimballing. The compass bowl is suspended in gimbals so that it remains horizontal in a seaway. It is desirable to have the fore-and-aft axis of the gimballing on the outer arc, otherwise in heavy rolling and pitching the lubber's line will move slightly with respect to the fore-and-aft line of the ship, thus reducing, to a small extent, the accuracy of the instrument.

Expansion. The bottom of the bowl of modern compasses is fitted with a corrugated diaphragm to allow for the expansion and contraction of the liquid which occurs with a change of temperature.

Suspension. In order that compass cards shall remain as near to the horizontal as possible, they are suspended with their pivoting point above the centre of gravity of the card and needles, as shown in figure 114.

DESCRIPTION OF THE VARIOUS TYPES OF COMPASSES

Pattern 193, 195, and 188 Compasses. The compass card is made of mica and is secured to two needles and a copper float. The

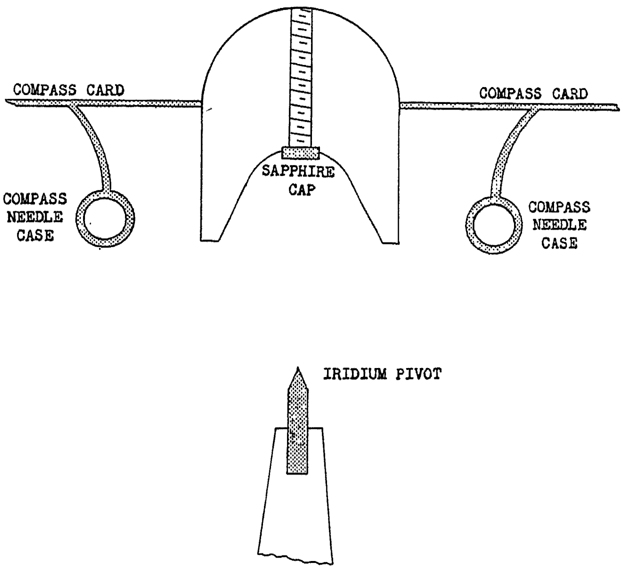


FIGURE 114.

needles are cased in brass to prevent rust and consequent loss of magnetism.

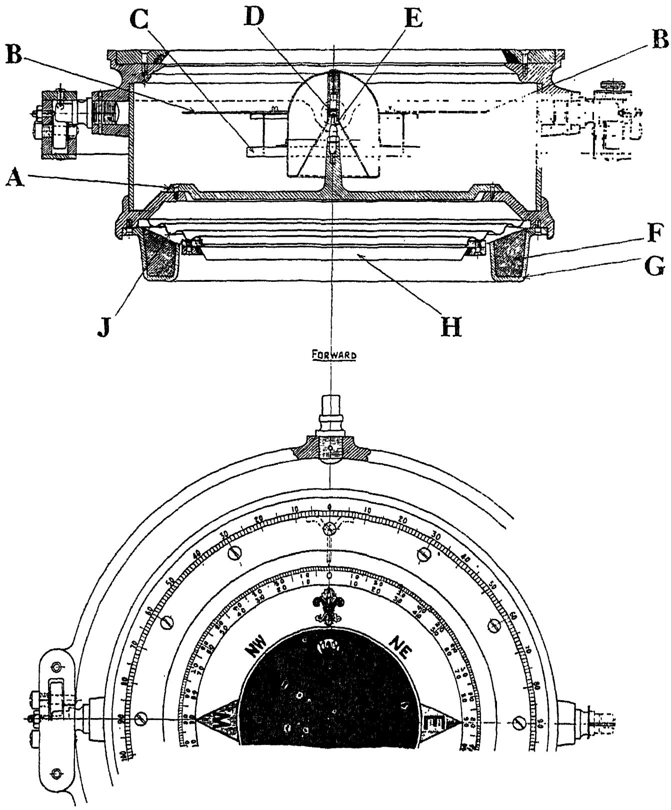
The point of support is a sapphire cap inside the copper float, which rests on an iridium pivot, as shown in figure 114.

The compass bowl, shown in figure 115, is made of brass, with a plain glass top and a frosted glass bottom to diffuse the light. Between the frosted glass bottom and the sides of the bowl is the corrugated diaphragm which allows for expansion. Rubber washers are inserted between the sides and the glass faces to make the bowl watertight and prevent the liquid escaping.

Brackets are fitted inside the bowl to carry the pivot, and outside the bowl to carry the gimbal pins.

A lead ring is fitted to the bottom of the bowl to give sufficient weight to keep the bowl horizontal.

The lubber's point is fixed inside the bowl.



A. Bridge.
B. Card.
C. Magnet.
D. Jewel.
E. Pivot.
F. Lead filling for balance weight
G. Balance weight.
H. Bottom glass.
J. Expansion diaphragm.

FIGURE 115.

Pattern 183 Compass (Boat compass). This compass is of similar construction with the exception that it has no glass bottom. The bottom consists of a metal expansion chamber which can be worked by a screw. The nut to work this screw is kept in the inside of the cover.

An oil lamp is fitted in a bracket casing on the side of the binnacle.

Pattern 28P (Submarine Projector). This compass, fitted in a watertight tube, has a suitably placed glass window to enable it to be used, in most submarines, as a steering compass on the bridge. A portion of the card is reflected down into the control-room.

CORRECTORS USED WITH NAVAL-TYPE BINNACLES

To counteract the magnetism of the ship the following correctors are used :

1. Horizontal magnets 8 inches long, of $\frac{3}{8}$ or $\frac{3}{16}$ inches diameter.
2. Vertical magnets 9 inches long, diameter $\frac{3}{8}$ inches.
3. Spheres or soft-iron balls in various diameters from 2 to 10 inches.

Those of diameter 6 inches and below are solid ; those above 6 inches in diameter are made hollow to reduce weight.

Each sphere has a brass disc on it, and *spheres should always be shipped with the brass disc facing aft.*

After spheres have been shipped, the letters P and S should be stamped on the brass discs to indicate port and starboard.

4. Flinders' bar ; a soft-iron bar 3 inches or 2 inches in diameter. The 3 inch bar is supplied in pieces of 12, 6, 3, $1\frac{1}{2}$ inches and two pieces of $\frac{3}{4}$ inch, total length 24 inches.

The 2 inch bar is supplied in lengths 6, 3 and two $1\frac{1}{2}$ inch pieces ; total length 12 inches.

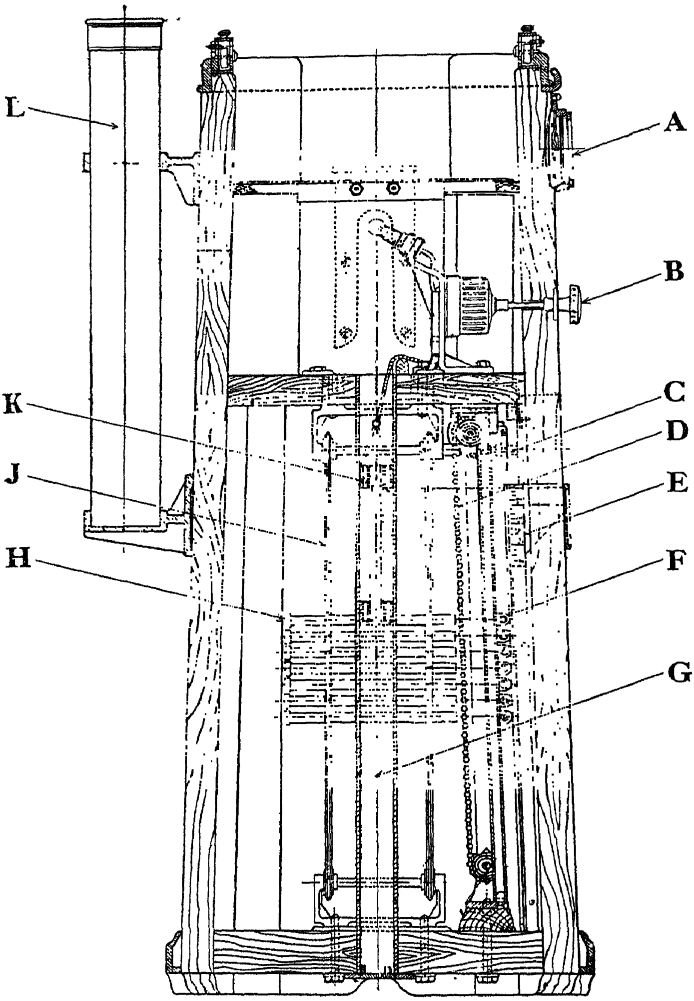
The poles of the Flinders' bar, when it is magnetised by induction, are about $\frac{1}{12}$ of its length from its ends.

When a Flinders' bar is required to correct a compass, it is necessary that its upper pole should be in the same horizontal plane as the compass needle. To enable this to be done, wooden blocks of suitable size are supplied. According to the length of Flinders' bar required so the wooden blocks are put below the pieces of iron to obtain the required height.

DESCRIPTION OF VARIOUS TYPES OF BINNACLES

Pattern 194 Binnacle. Fleet Type, shown in figure 116.

1. The upper part is the stowage position for the compass, and includes the roller supports for the outer gimbal pivots of the compass.
2. The centre part contains an electric lamp for lighting the bowl, a hole for the carrier of the vertical magnets, and stowage for an oil lamp.
3. The lower part contains the brass carriers for the horizontal magnets, which can be raised or lowered by a system of endless



A. Clinometer.
B. Dimmer knob.
C. Operating head for fore-and-aft magnets.
D. Chain for athwartship magnets.
E. Scale for fore-and-aft magnets.
F. Athwartship magnet tubes.
G. Tube for vertical magnet bucket.
H. Fore-and-aft magnet tubes.
J. Chain for fore-and-aft magnet tubes.
K. Bucket for vertical magnets.
L. Flinders' bar tube.

FIGURE 116.

chains and wheels, operated by a spanner. This spanner is stowed in a niche just forward of the 'safety door'. The wheels are kept from moving by pawls held down by studs on the doors.

By the 'safety door' of this part there is a clip used to hold the chain that raises and lowers the bucket. This chain is marked in inches to show the distance of the top of the magnet from the compass needles.

Scales are fitted inside the lower portion to show the distance in inches of the horizontal magnets from the compass needles.

In the latest binnacles the light for the compass bowl is regulated by a dimmer switch. In older binnacles a sliding shutter, worked from the outside, is fitted between the upper and centre portions of the binnacle.

Brackets are fitted on the sides of the binnacle to support the spheres and the Flinders' bar.

In the latest binnacles the brackets for the spheres are marked in inches to show the distance between the centres of the spheres and the centre of the compass card.

Pattern 196 Binnacle (Flotilla type). These are similar to the pattern 194 binnacle, except that the horizontal magnets are placed in holes fitted in the binnacle.

These holes are numbered for reference, no scales being fitted as in the pattern 194. The oil lamp is fitted in the hood of the binnacle.

Pattern 189 and 185 Binnacles (Submarine compass). These are similar to pattern 196 binnacle, except that:

1. no Flinders' bar is fitted.
2. no movable vertical bracket is fitted, the whole adjustment for heeling error being made by varying the number of magnets.

Pattern 1830 Binnacle. Only horizontal magnets can be placed.

CARE AND MAINTENANCE

Repairs. The whole work of testing and repairing compasses is carried out at the Admiralty Compass Department, Slough.

Defective compasses should be returned through the N.S.O. and new compasses drawn to replace them.

H.M. dockyards undertake minor repairs to binnacles.

Keys. The navigating officer is responsible for the binnacle keys. Binnacles should be kept locked. (K.R. & A.I. Article 1188.)

Stores. Compasses, binnacles, Flinders' bar, and spheres, are permanent sea stores.

Corrector magnets are consumable stores.

Alteration of Position of Binnacles. The positions of binnacles are not to be altered without Admiralty authority. (K.R. & A.I. Article 1188.)

Removing a Bubble. Sometimes a bubble forms in the compass. This makes the card difficult to read and less sensitive. For these reasons the bubble must be removed.

1. *With compasses fitted with corrugated expansion chambers*, unship the bowl from the gimbals and lay it on its side with the filling hole uppermost. Remove the filling plug from the filling hole and work the expansion chamber by pressing on the frosted glass bottom, at the same time filling the bowl with distilled water. During this procedure rock the bowl from side to side to assist any air to escape. Release the expansion chamber and continue the operation until all air is removed. Replace the filling plug.

2. *With compasses fitted with nut and screw expansion chambers*, take the nut from its stowage position and turn the compass so that the filling plug is uppermost. Remove the filling plug ; place the nut on the expansion screw thread and *screw it hard up*. Fill the bowl with distilled water, rocking it to assist the air to escape. When the water overflows, unscrew the nut about two turns. This will cause more water to overflow. Replace the filling plug and unscrew and remove the nut. This leaves the bowl with a slight pressure inside it.

NOTE. The nut used with the expansion chamber is fitted :

(*a*) in pattern 183 compasses, in the cover.
(*b*) in pattern 188, 173, and 28P compasses, in the stowage box.

A bubble generally indicates a leak and therefore a defective compass, which should be returned at the first opportunity and a new one drawn to replace it.

Compasses are supplied with their bowls filled with a mixture of alcohol and distilled water. The alcohol is added to reduce the freezing point of the mixture.

TABLE I

Correction of quadrantal deviation by spheres

Compasses patt. 22A and 22. Binnacle patt. 44A, using spheres patt. 405.
Compass patt. 193. Binnacle patt. 194, using spheres patt. 405.

Distance of the centre of compass to centre of sphere	Amount of D corrected by a pair of:											
	5″ spheres		6″ spheres		7″ spheres		$8\frac{1}{2}$″ spheres		10″ spheres		12″ spheres	
″	°	′	°	′	°	′	°	′	°	′	°	′
15·5	0	50	1	20	2	25	3	45	6	00	9	00
15·25	0	52	1	22	2	28	3	55	6	10	9	35
15·0	0	54	1	24	2	34	4	09	6	20	10	18
14·75	0	57	1	26	2	40	4	25	6	30	11	05
14·5	1	00	1	30	2	48	4	42	6	55	12	00
14·25	1	03	1	35	3	01	5	00	7	25		
14·0	1	07	1	41	3	15	5	20	7	55		
13·75	1	11	1	48	3	29	5	42	8	25		
13·5	1	15	1	55	3	44	6	07	9	05		
13·25	1	19	2	03	4	00	6	34	9	50		
13·0	1	24	2	12	4	17	7	02	11	02		
12·75	1	30	2	22	4	35	7	32				
12·50	1	37	2	32	4	54	8	09				
12·25	1	45	2	43	5	16	8	52				
12·0	1	55	2	56	5	40						
11·75	2	06	3	12								
11·5	2	19	3	30								
11·25	2	33										
11·0	2	50										

TABLE I

Correction of quadrantal deviation by spheres

Compass patts. 24C and 173. Binnacle 172 using spheres patt. 174.
Compass patt. 195. Binnacle 196 using spheres patt. 404.

Distance of the centre of compass to centre of sphere	Amount of D corrected by a pair of: 4″ spheres		5″ spheres		6″ spheres		7″ spheres		8½″ spheres		10″ spheres	
″	°	′	°	′	°	′	°	′	°	′	°	′
12·5	0	30	1	10	2	30	3	50	6	10	10	05
12·25	0	35	1	20	2	50	4	10	6	55	11	25
12·0	0	40	1	35	3	10	4	35	7	45	12	50
11·75	0	50	1	50	3	30	5	05	8	35	14	30
11·5	1	00	2	05	3	50	5	40	9	30		
11·25	1	10	2	20	4	10	6	15	10	30		
11·0	1	20	2	35	4	35	6	50	11	35		
10·75	1	30	2	50	5	0	7	30				
10·5	1	40	3	10	5	25	8	10				
10·25	1	50	3	30	5	55	9	00				
10·0	2	10	3	50	6	25						
9·75	2	15	4	10	7	00						
9·5	2	35	4	35								
9·25	2	55	5	05								
9·0	3	20										
8·75	3	50										

TABLE I

Correction of quadrantal deviation by spheres

Compass patt. 158. Binnacle patt. 159 using spheres patt. 410.

Distance of the centre of compass to centre of sphere	Amount of D corrected by a pair of:			
	10″ spheres		12″ spheres	
″	°	′	°	′
13·5	8	30	17	40
13·25	9	10	19	00
13·0	9	55	20	30
12·75	10	40	22	10
12·5	11	25	24	00
12·25	12	10	26	30
12·0	13	00		
11·75	13	55		
11·5	15	00		
11·25	16	15		
11·0	18	00		

TABLE I

Correction of quadrantal deviation by spheres

Compass patt. 184. Binnacle patt. 185 using spheres patt. 402 *et seq.**
Compass patt. 188. Binnacle patt. 189 using spheres patt. 402 *et seq.**

Distance of the centre of compass to centre of sphere	Amount of D corrected by a pair of:					
	2″ spheres		3″ spheres		4″ spheres	
″	°	′	°	′	°	′
7·5			1	45	3	15
7·25			2	00	3	45
7·0			2	15	4	25
6·75			2	35	5	15
6·5			2	55	6	10
6·25			3	20	7	05
6·0			3	45	8	00
5·75			4	20	9	00
5·5			5	00	10	00
5·25			5	50		
5·0	1	30	6	50		
4·75	2	25				
4·5	3	30				

* Special 4″ spheres with a flattened base (patt. 404S) are required for use on these binnacles.

TABLE I

Correction of quadrantal deviation by spheres

Compass patt. 28P. Binnacles R.L.V, R.L.VI, R.L.VII using spheres patt. 404.

Distance of the centre of compass to centre of sphere	Amount of D corrected by a pair of:							
	4″ spheres		5″ spheres		6″ spheres		7″ spheres	
″	°	′	°	′	°	′	°	′
10·5	1	20	2	05	3	30	6	25
10·25	1	20	2	15	3	45	6	55
10·0	1	25	2	25	4	00	7	30
9·75	1	30	2	40	4	20	8	10
9·5	1	35	2	55	4	45	8	55
9·25	1	45	3	10	5	10	9	45
9·0	1	55	3	25	5	40	10	45
8·75	2	05	3	45	6	10	11	50
8·5	2	15	4	10	6	45		
8·25	2	30	4	35	7	30		
8·0	2	50	5	05				
7·75	3	10	5	40				
7·5	3	35						
7·25	4	00						

NOTE. The side of the binnacle is 5″·25 from the centre of the compass. Thus, where the sphere brackets are not marked, the distance can be found by adding 5″·25 to the distance of the centre of the sphere to the side of the binnacle.

TABLE I

Correction of quadrantal deviation by spheres

Compass patt. 921. Binnacle patt. 922. using spheres patt. 175.

Distance of the centre of compass to centre of sphere	Amount of D corrected by a pair of:			
	5″ spheres		6″ spheres	
″	°	′	°	′

TABLE II

Correction of 'c' by Flinders' Bar

Binnacles patt. 44A, 194, using 3″ Flinders' bar patt. 45 at 11″. Centre of compass to centre of bar.
Binnacle patt. 196, using 3″ Flinders' bar patt. 45 at 9″·5. Centre of compass to centre of bar.
Binnacles patt. 172 (and 196) using 2″ Flinders' bar patt. 197 at 9″. Centre of compass to centre of bar.
Binnacle patt. 922 using 2″ Flinders' bar patt. 197 at 8″. Centre of compass to centre of bar.

Value of 'c'	Length of bar			
	3″ bar (patt. 45)		2″ bar (patt. 197)	
	Binnacles patts. 44A, 194	Binnacle patt. 196	Binnacles patts. 172, 196	Binnacle patt. 922
	″	″	″	″
·01	5·9	5·6	4·8	
·02	8·0	7·0	6·8	
·03	9·6	8·0	8·4	
·04	10·9	9·1	9·6	
·05	12·1	10·0	10·2	
·06	13·2	10·8	12·1	
·07	14·2	11·6		
·08	15·2	12·4		
·09	16·3	13·2		
·10	17·4	14·0		
·11	18·4	14·8		
·12	19·4	15·6		
·13	20·4	16·4		
·14	21·4	17·2		
·15	22·4	18·0		
·16	23·4			
·17	24·4			
·18				
·19				
·20				
·21				
·22				

NOTE. When 'c' has the sign +, the bar is required on the after side of the binnacle. When 'c' has the sign —, the bar is required on the fore side of the binnacle.

RULES

To be Attended to in the Arrangement of Structure and Fittings in the Vicinity of Compasses and Chronometers

1. In the early stages of design the compass positions are to be indicated on the plans and when agreed to by D.C.D. will be submitted to the Third Sea Lord.

2. The standard compass is to be at the position from which the vessel is navigated and manœuvred, and the view therefrom is to be as unobstructed as possible.

3. No iron or steel other than that of a non-magnetic variety is to be placed within 10 feet of the standard compass, except in ships that carry two gyro compasses. In these ships it is permitted to build steel decks and overhead plating up to a thickness of 1 inch with material for which the coefficient μ does not exceed 100. (See Volume III.)

4. The extremities of elongated masses of iron or steel should be as far as possible from the compass. The nearest funnel should not be nearer than 32 feet. Other iron or steel masses such as conning towers, turrets, should not be less than 20 feet from the standard compass.

5. No iron or steel subject to occasional movement is to be placed within 12 feet of the standard compass.

6. If there would be great difficulty and expense in complying with the above regulations, a conference should be held between D.N.C., D.C.D., and other departments concerned to consider the matter and submit proposals.

7. The directive force being considerably less in the lower conning tower than at standard positions, it is necessary, in order to obtain reasonable accuracy, to keep disturbing elements at an equal or a greater distance.

In arranging the position of the compass in the L.C.T., therefore, the following distances are to be worked to :

Movable iron or steel	12 feet.
Fixed iron or steel (other than decks or bulkheads)	10 feet.

Bulkheads which are situated within 4 feet of the compass to be made of non-magnetisable material, for a distance of 10 feet in the horizontal plane and 4 feet in the vertical plane from the centre of compass, and doors, hatches, etc., within 12 feet to be made of non-magnetisable material.

It is most undesirable to allocate spaces in the vicinity of the lower conning tower for stowage of magnetisable material, such as projectiles, etc.

8. Where other magnetic compasses are fitted, these should be safeguarded as far as possible and not brought nearer to vertical iron than 6 feet.

9. Especial care is necessary in allotting positions for electrical machines and instruments; a list of minimum distances to be maintained between them and the standard and lower conning tower compasses is attached.

10. The minimum distances between chronometers and electrical fittings to be half the distances given for standard compasses.

Description of Electrical Gear	*Minimum Distance from* *Standard.* feet	*L.C.T.* feet
Aldis lantern, magnetically operated	2	3
Alternator, motor, type 1,100 volts	13	18
,, ,, type 1,220 volts	13	18
,, ,, type 9,100 volts	4	6
,, ,, type 8,220 volts	4	6
,, ,, 5 K.W., 100–140 volts		
,, ,, 5 K.W., 180–220 volts		
,, ,, type 10	4	6
Ammeters, various	3	3
Ampere gauges	3	3
Ampere hour meter for secondary batteries ..	5	7
Auto starter for submersible pumps	10	13
Bell, electric, all types	2	3
Box, terminal, connecting, type 81	6	8
Branch breakers (Whipp & Bourne, 100 volts) ..	6	8
,, ,, ,, ,, 220 ,, ..	10	12
,, contactors ,, ,, 100 ,, ..	6	8
,, ,, ,, ,, 220 ,, ..		
Buzzer, loud sounding	2	3
Buzzer	2	3
Buzzers, electric, all types	2	3
Circuit breakers for L.P. supply		
Charging board for secondary cells	5	7
Clear-view screen, motor driven (Kent: 20 volts)	3	–
Converter, rotary, type 2, 100 volts..	4	6
,, ,, type 2, 220 ,, ...		
,, ,, type 4, 100 ,, ...		
Dimming switches	3	4
Distribution boxes, 5-way	3	4
,, ,, 8-way	3	4
,, ,, switchless	3	4
D.P. switch and terminal boxes	4	6
Dreyer table		
Dynamos, various		
Dynamo change-over switches		
Dynamotors for Sperry compass, all patterns ..	10	13
Electro-megaphone	6	8

Description of Electrical Gear	*Minimum Distance from Standard.* feet	*L.C.T.* feet
Electro-megaphone patt. 9280 receiver	4	6
,, ,, patt. 9281 transmitter ..	5	7
Engine direction tell-tales, Chadburn's	3	4
,, room order repeater, Chadburn's	10	10
,, telegraph order repeaters, Chadburn's ..	4	6
Evershead open-faced indicator, all types	3	4
,, transmitter for bearings and orders ..	3	4
,, ,, receiver for bearings and orders	3	4
,, receiver for bearings and orders	3	4
,, isolator, 600-watt size		
,, ,, 1,200-watt size		
,, ,, starter for 220-volt supply ..		
Forbes log, speed indicator	1	2
,, ,, distance recorder	1	2
Gas-mask telephone	1	2
Gong, cease fire, electric	2	3
,, engine room, reply	3	4
Henderson gyro	2	3
Helm indicator	$4\frac{1}{2}$	$4\frac{1}{2}$
,, transmitter and receiver	3	4
Hot cupboard	4	6
,, plate	4	6
Hummer, 15-volt	2	3
Instruments and repeaters for fire control and other services containing one or more motors of the following types :		
Admiralty ' M ' type, small, 2-pole	2	3
,, ,, medium 4-pole ..	2	3
,, ,, large 8-pole	2	3
Barr & Stroud..	4	5
Elliott Bros.	2	3
Graham	3	4
Sperry	2	3
Vickers	2	3
Junction boxes, 4-way	3	4
,, 8-way	3	4
Kent clear-view screens, 20-volt motor	3	–
Key, Morse	2	3
Lamps, incandescent, electric, for 100 volts ..	1	2
,, ,, ,, for 220 ,, ..	1	2
,, ,, ,, portable, with iron guard		
Line coil boxes for navyphone circuits	3	4

Description of Electrical Gear	*Minimum Distance from Standard.* feet	*L.C.T.* feet
Link boxes	3	4
,, ,, all sizes	6	8
Low-power supply panels, all types	8	12
Manœuvring-light flashing keys, switches and circuits	3	4
Microphone, with hand mounting, type 81 ..	4	6
Milking booster and starter for L.P. circuits ..	4	6
Motor alternators and starters for :		
Henderson gear	12	15
Hummers		
Turret danger signals	20	28
Motors, fans, 5″ (all makers)		
,, ,, 7½″ ,, ...	6	9
,, ,, 12½″ ,, ...	12	15
,, ,, 17½″ ,, ...	12	15
,, ,, 25″ ,, ...	9	12
,, ,, 30″ ,, ...		
Motors below 5 B.H.P., various makers		
,, from 5 to 25 B.H.P. various makers ..		
,, ,, 25 to 75 B.H.P. ,, ,, ..		
,, ,, 75 B.H.P. and above, various makers		
Motor generators and starters for L.P. supply ..		
,, ,, for Sperry compass	10	14
,, ,, type 14, 100–140 volts (submersible design)	10	13
,, generator, type 14, 100–140 volts (Laurence Scott design)		
,, ,, type 15, 100 volts..		
,, ,, type 18, 100 volts..		
,, ,, type 18, 220 volts..		
,, ,, 750-v, type 31, 100 volts.. ..		
,, ,, 750-v, type 31, 220 volts.. ..		
,, ,, 10-v, 300 watts, 100-volt supply	6	8
,, ,, 10-v, 300 watts, 220-volt supply		
,, ,, 17-v, type 31, 100 volts		
,, ,, 17-v, type 31, 220 volts		
,, ,, 21-v, type 33, 100 volts		
,, ,, 21-v, type 33, 220 volts		
Navigation light, switches and circuits	2	3
Navyphones, all types	3	4
Non-inductive resistance for firing and N.S. circuits	2	3
Note generator		
,, sounder	3	4
Oscillator, 100–140 volts, types 101 and 102 ..		

Description of Electrical Gear	*Minimum Distance from* *Standard.* feet	*L.C.T.* feet
Radiators, 100 volts	3	4
,, 220 ,,	3	4
Rattlers, all types	3	4
Resistances, potentiometer, 110-v or 220-v	3	4
Reverse current breakers		
Ring-main fuse release switch		
,, ,, breakers	10	14
,, ,, switches	6	8
Searchlight projector, service, 36″	20	26
,, Sperry, 24″	8	12
,, service, 24″	10	14
resistance for 36″		
,, Sperry, 24″		
,, service, 24″	15	18
Section boxes	3	4
Service change-over switches		
Signalling projectors	6	8
Starters, automatic (with suitable resistances) (patterns 6947 to 6955)	10	13
Starters for motors and motor generators, all makers:		
Below 5 B.H.P.		
5 B.H.P. to 25 B.H.P.		
25 B.H.P. to 100 B.H.P.		
100 B.H.P. and above		
Starter, Admiralty pattern, light weight		
,, with contactor, Bray, Markham & Reiss, drum type		
,, separate relay for pusher hoist, Bray, Markham & Reiss		
,, for E.A. plant, Brookhirst, ratchet type		
,, for E.A. plant, Laurence Scott, auto type.		
,, for steering motor, Laurence Scott, auto type		
,, for 350-ton pump, Electric Control Co's automatic starter		
Switch starter for capstan and boat hoist, W.H. Allen's multiple-switch starter		
Supply breakers (Whipp & Bourne, 220 volts)	6	8
Switches and terminal box		
Switch, telephone	2	3
Telephones and headgear, complete, Brown's 120 ohms	3	4
Telephone receivers	3	4

Description of Electrical Gear	*Minimum Distance from Standard.* feet	*L.C.T.* feet
Transformer box for hummer circuits	3	4
Vickers range clock, transmitting type	3	4
Voltage regulator M/G for Sperry compass.. ..	10	13
Voltmeters, various (100 volts)	3	3
,, ,, (220 volts)	3	3
Warning telephone, control unit	4	6
,, ,, loud-speaking receiver ..	4	6

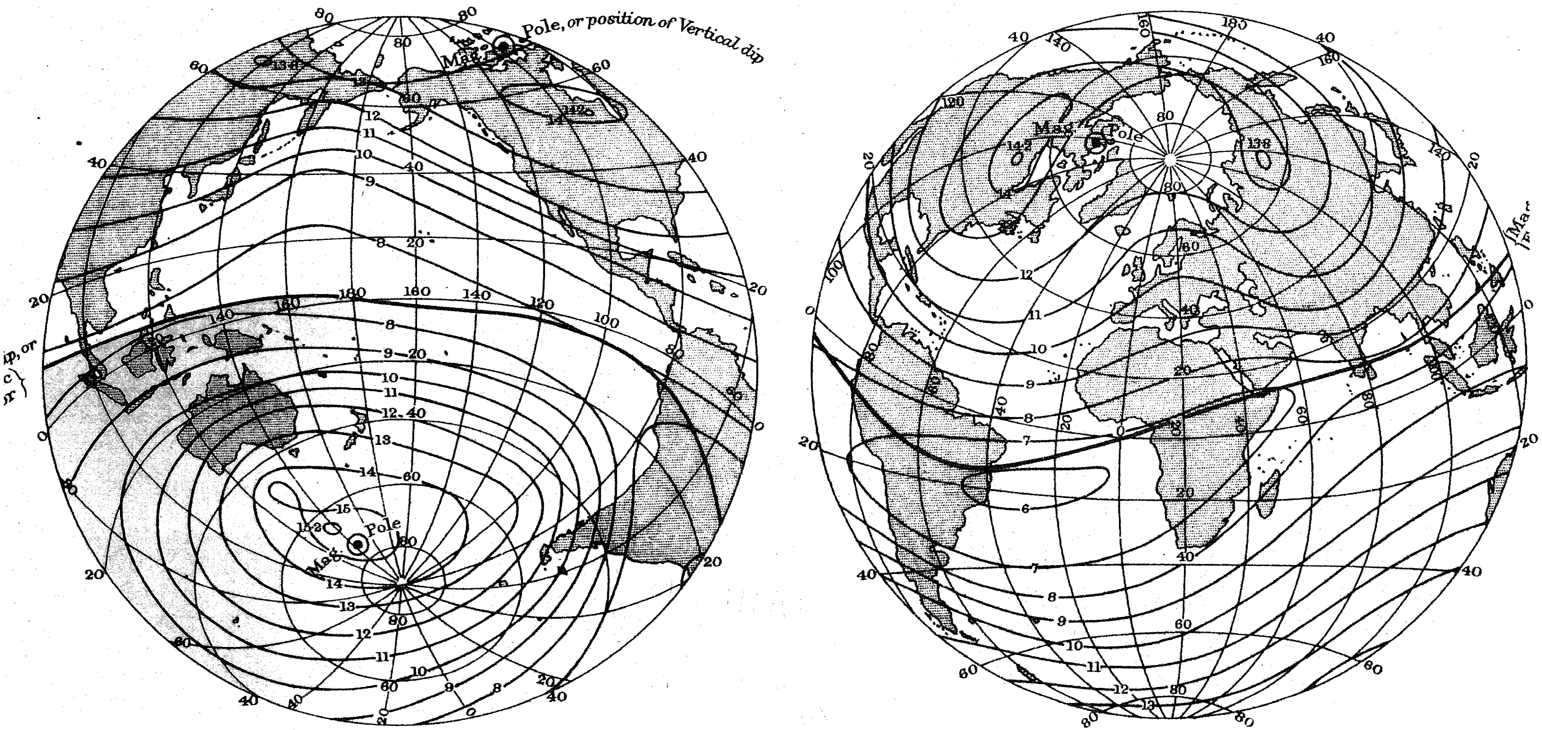
Remarks

It has not been possible to test all types of machines. If, therefore, a particular type is not shown, or if the type is shown and the safe distance is not given, the following rough distances should be worked to :

	feet	feet
Small motors below 5 H.P.	12	15
Motor generators, alternators, rotary converters ..	15	20
Dynamos	40	50

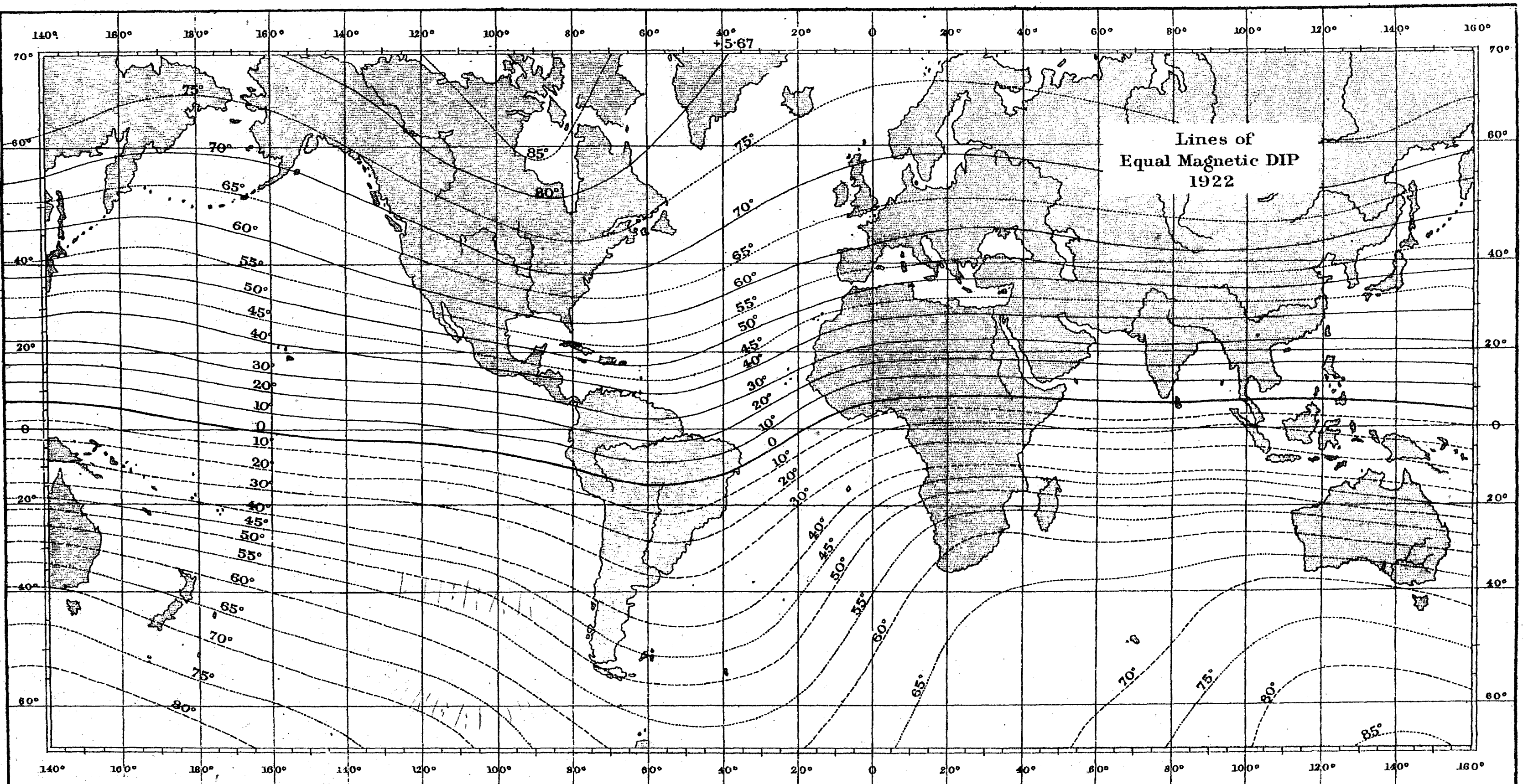
THE EARTH'S MAGNETISM

as shown by the distribution of lines of equal Total force
in Absolute measure British units; the position of the Magnetic Poles and
Equator with the regions of blue and red magnetism
(Approximately for 1875)



Misc. 63

niralty Navigation Manual, Vol. I.
5. WT 1189B/10,000. 7·43.
63 W^T 3230D/7,500. 1.45.



Admiralty Navigation Manual.

7126, WT 1189B/10,000.7·43

CHART II

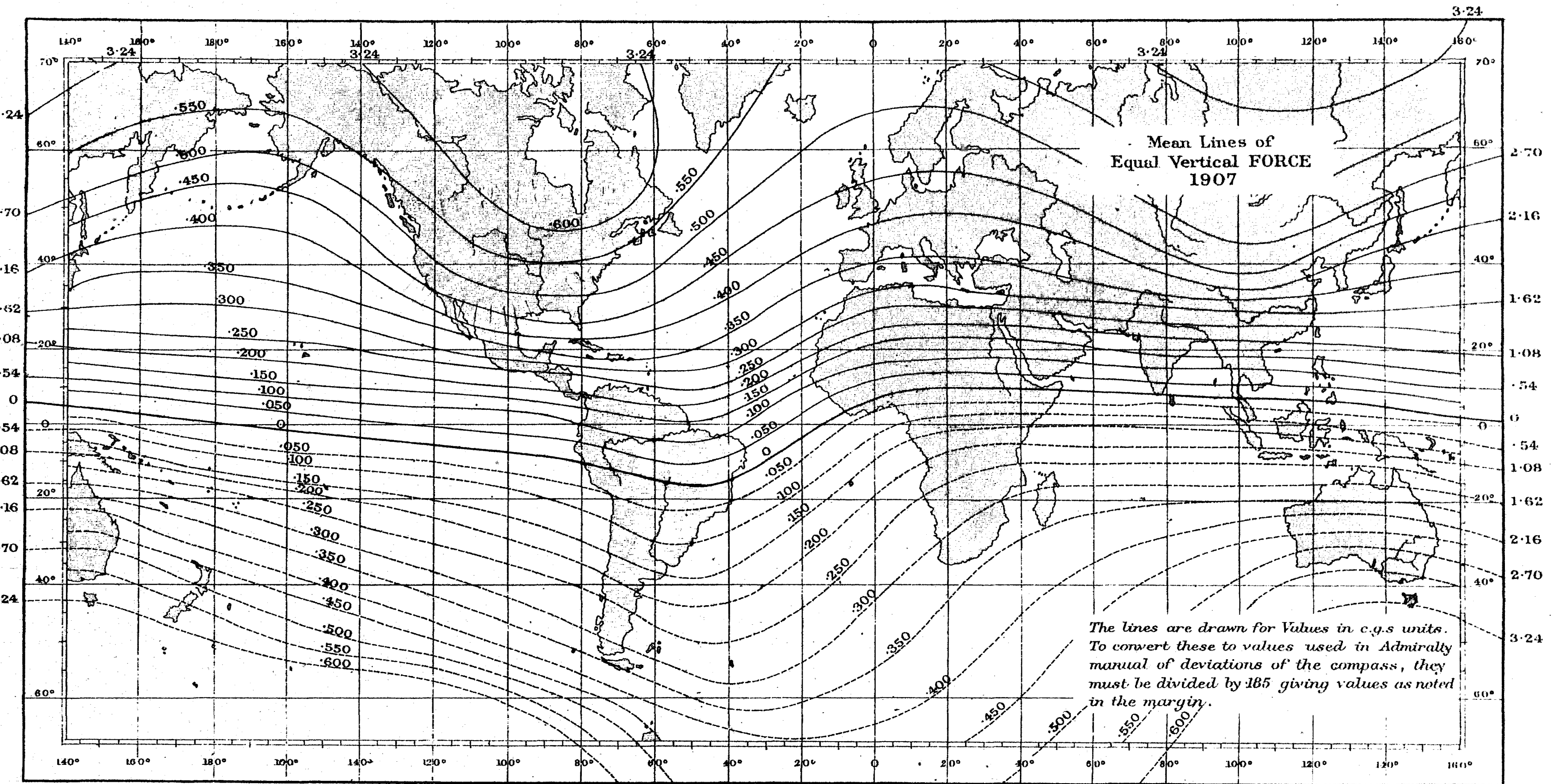
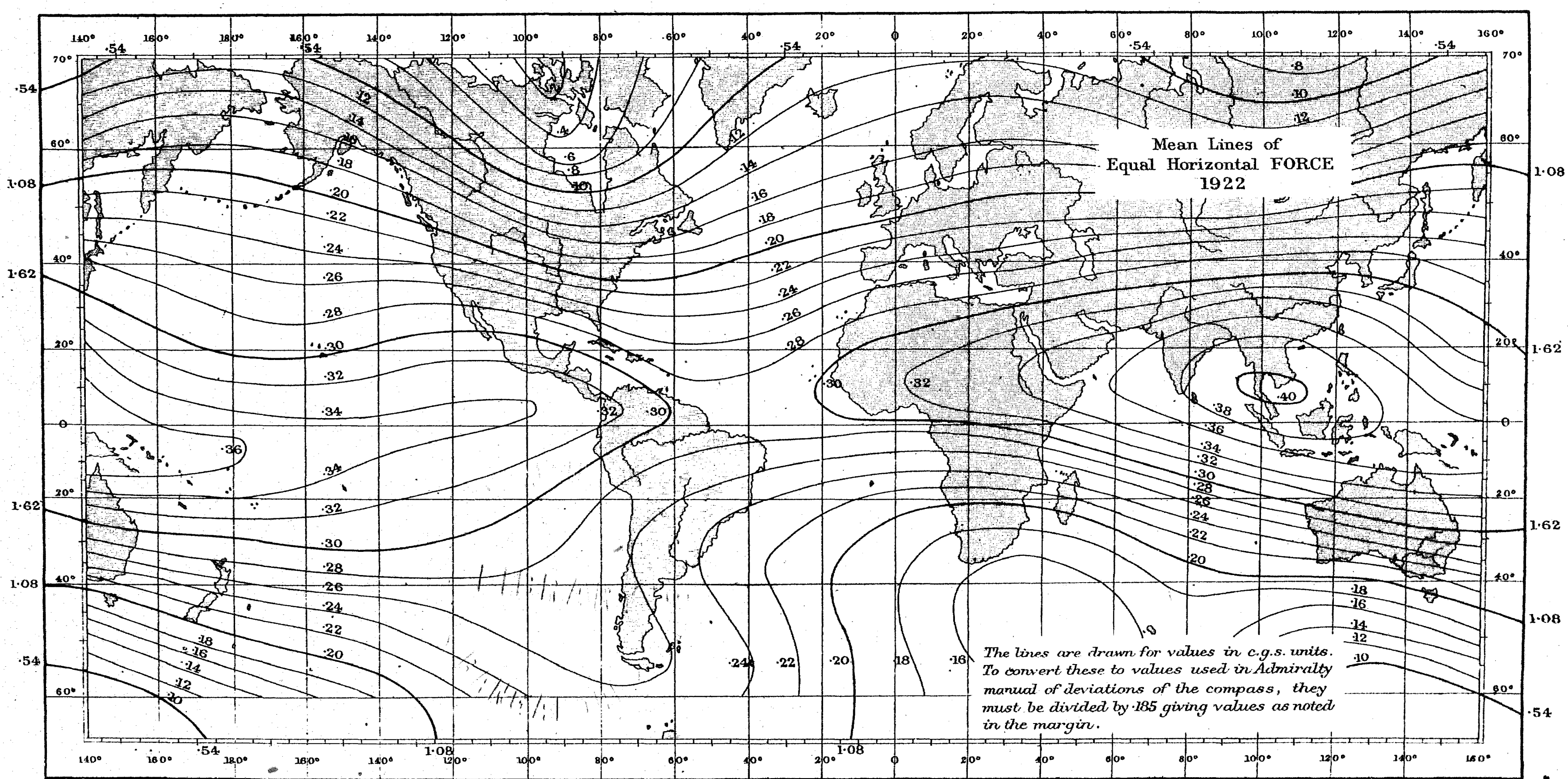

Mean Lines of
Equal Vertical FORCE
1907
The lines are drawn for Values in c.g.s units. To convert these to values used in Admiralty manual of deviations of the compass, they must be divided by ·185 giving values as noted in the margin.

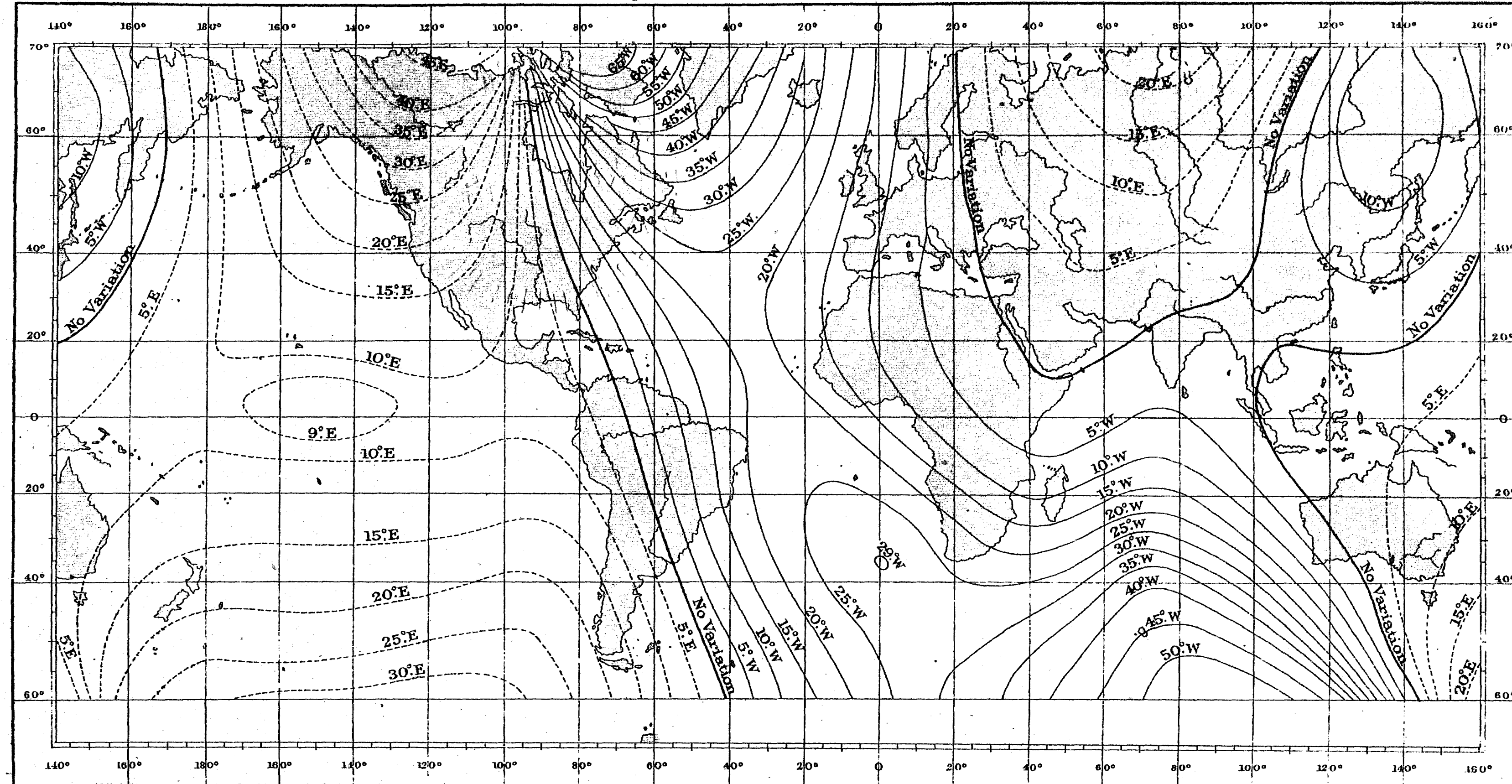
CHART III



Admiralty Navigation Manual.

CHART IV

LINES OF EQUAL MAGNETIC VARIATION 1937.



Admiralty Navigation Manual.

CHART V

CHAPTER XI

CHRONOMETERS AND WATCHES

Four types of time-keeping instruments are supplied to H.M. ships for navigational purposes: chronometers, chronometer watches, deck watches and pocket watches.

Chronometers are supplied to H.M. ships according to the work on which the ships themselves are likely to be employed. The approximate value of a chronometer is £40.

Chronometer Watches (C.W.) are supplied instead of chronometers to small ships. These are delicate and expensive instruments, and, if properly treated, give results equal to those given by chronometers. The approximate value of a chronometer watch is £22.

Deck Watches (D.W.) are supplied for bridge use, because chronometers or chronometer watches are not allowed to be moved from their permanent stowage. When not being used they are to be kept in the chronometer case. The approximate value of a deck watch is £6.

Pocket Watches are supplied instead of deck watches to certain small ships and are used for similar work. The approximate value of a pocket watch is £2.

SUPPLY OF CHRONOMETERS

The navigating officer of a ship about to be commissioned at a home port should apply to the Hydrographer for the chronometers and watches allowed by establishment (Form H.110). Because changing position and travelling considerably affect chronometer rates for some days, it is a great advantage to obtain the chronometers as early as possible. They can then settle down to a steady rate.

They will usually be supplied from the Royal Observatory, Greenwich. Chronometers are despatched *wound and stopped*, and they should be unpacked and started as described later.

If a ship is recommissioning at a port abroad, application should be made to the nearest chronometer depot.

Chronometer Depots are established abroad at Gibraltar, Malta, Port Said, Singapore and Hong Kong dockyards, and also at the Cape of Good Hope Observatory. In addition, small stocks of chronometers and watches are kept at Colombo Observatory, and by the Master Attendant at Bermuda.

A few chronometers and watches are also kept at the chart

depots at Plymouth, Portsmouth and Sheerness, but these are supplied to ships only in emergency.

If chronometers are drawn by hand from a depot, they are supplied *wound and running*.

When supplied, the chronometers are accompanied by a supply note (S.383) on which is stated :

1. the names of their makers.
2. their official numbers.
3. their dates of issue from the Royal Observatory.

If they are supplied running, the following additional information is given :

4. their rates.
5. the mean temperature since they were last rated.

On receiving the chronometers and watches, a receipt note (S.383) is to be sent to the officer who supplied them, and a return, on form S.379, is to be forwarded immediately to the Hydrographer.

If chronometers are supplied from the Royal Observatory, in addition to the supply note, they are accompanied by an abstract of rates, which gives the rates of the chronometer during the previous few months.

The Date of Issue from the Royal Observatory is stated :

1. on the supply note.
2. on the label inside the case.

This information should be entered on the front page of the chronometer comparison book.

THE ESTABLISHMENT OF CHRONOMETERS AND WATCHES

Each battleship, battle-cruiser, cruiser or sloop on a foreign station is allowed three chronometers and one deck watch. Ships carrying midshipmen will be supplied, on demand, with two additional deck watches to be used for instruction. Other ships are allowed timekeepers as shown on form H.110.

MOVING CHRONOMETERS

The navigating officer should always supervise the transport of chronometers. The greatest care must be taken to prevent any shock, vibration, or twisting movement, for which reason they should not be moved during bad weather except in emergency. The gimbals should be locked before transport and not unlocked until the final destination is reached.

THE STOWAGE OF CHRONOMETERS

Chronometers are stowed in the chronometer room which is so placed that it is :

1. free from damp.
2. away from vibration.

3. away from traffic.
4. at an even temperature.
5. behind armour for protection.
6. not directly against an armoured bulkhead.
7. able to comply with regulations concerning safe distances from electrical instruments. (No electrical instrument should be allowed within *one half the distance* given in the tables for the standard compass on pages 266 to 270.)
8. accessible.
9. near the pivoting point of the ship.

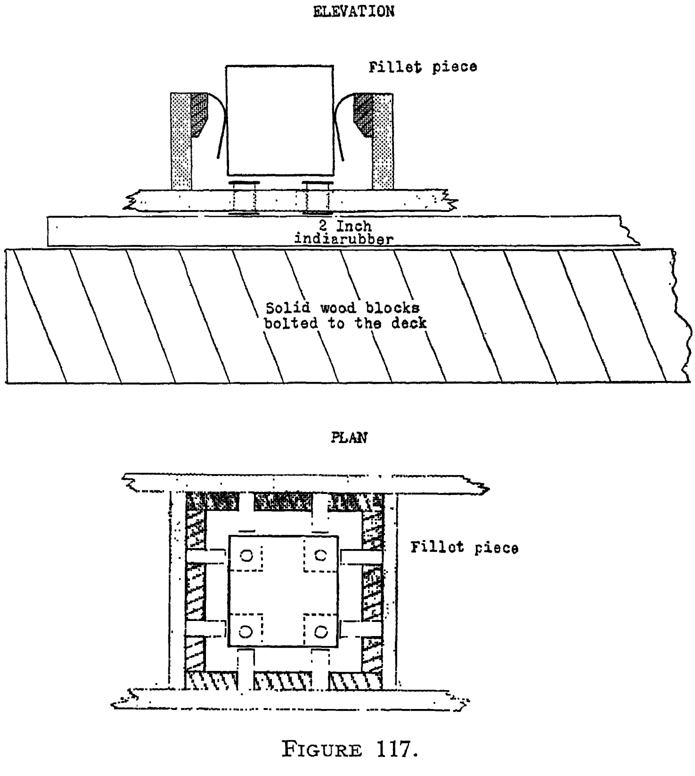


FIGURE 117.

In the chronometer room is a stand consisting of specially prepared blocks of well-seasoned wood, about 2 feet deep, bolted to the deck. On the top of these blocks is a sheet of indiarubber, and on top of this is the box with three or five compartments for the chronometers. These compartments are fitted with springs at the bottom and on the sides to hold the chronometers firmly, as shown in figure 117. The chronometer box itself is merely a wooden cover for these compartments and does not touch the stowage. Thus any knock on the former will not be communicated to the chronometers.

The tills of chronometer boxes are fitted with springs for holding the chronometer cases in position.

In order to adapt the compartments to hold smaller chronometers, strips of wood, called fillet-pieces, are supplied. These strips are to be planed to a suitable thickness, cut up and screwed to the inside of the compartment, and the springs then fixed to the strips, as shown in the figure. This fitting requires accurate workmanship and should be carried out by a joiner.

Should there be unavoidable delay in making this fitting, as may occur when ships in reserve are suddenly mobilised, the chronometers may be temporarily cushioned with *dry* waste until there is an opportunity for making the permanent fitting.

The outer lid of each chronometer should be removed from its hinges in order to allow the face of the chronometer to be seen through the glass top of the inner lid.

The best chronometer—that is the one with the most regular rate as shown by the abstract of rates—is called 'A', the next 'B' and the next 'C'. 'A' chronometer is put in the centre compartment, 'B' on one side of it and 'C' on the other. The gimbal rings are then unlocked. The letter of each chronometer should be marked on a small piece of paper gummed on the glass lid.

Chronometers and chronometer watches should never be moved from their stowage positions. Deck watches and pocket watches are supplied for taking observations and for use on the bridge. Any trace of moisture found on the glass cover should be removed.

Battle Stowage. This is laid down in K.R. & A.I. Art. 1195.

UNPACKING AND STARTING

(See form H.112)

To Unpack and Start a Chronometer. Carefully remove the packing and dust inside the wooden box before taking the wrapping of thin paper from the chronometer. Find the packet of screws that fix the gimbal ring to the wooden box. Unscrew the glass face; grasp the brass case at the base with the right hand, and place the fingers of the left hand carefully round the edge of the metal face.

Now turn the chronometer over until it falls gently out of its case into the left hand. If it sticks, it can be pushed out by inserting the key and gently bearing down.

Remove the cork wedges from underneath the balance wheel by drawing them out in a direction parallel with the plate. Whatever pressure is exerted should act on the plate and *not* on the balance. Screw on the glass face. This operation should not start the chronometer. Screw the gimbal ring on the chronometer, taking care that the slit for the locking apparatus is in its correct position; then take hold of the chronometer with the left hand, the thumb being on the face and the fingers on the base; incline it sideways in its gimbal ring, and screw it in its correct position in the wooden box.

The chronometer is now ready to be started at any required time by giving a circular motion to the box, care being taken that the movement is horizontal and not vertical.

To Start a Chronometer Watch, Deck Watch or Pocket Watch. Open the case, cut off the bent narrow end of the paper through the balance wheel and withdraw the remainder of the paper.

If the bent end of the paper is not cut off, it is apt to damage the balance wheel as it is withdrawn.

WINDING

Chronometers are wound daily at the same time, if possible, and at the same speed, by the same person. A dial on the face shows whether a chronometer is wound, or the number of hours since it was last wound. Chronometers are wound by turning the key anti-clockwise. The key, called a 'tipsy key', is fitted with a ratchet so that if it is turned in the wrong direction no strain is brought on the winding mechanism.

To wind a chronometer, turn it over gently in the gimbal ring, face down, holding it firmly with the left hand. With one finger of the left hand open the dust cap, and with the right hand insert the key and wind gently and evenly, counting the turns until the key is felt to butt and will wind no further. Be most careful not to force or jerk.

A one-day chronometer (30-hour) takes about ten half-turns daily.

A two-day chronometer (54-hour) takes about seven half-turns daily.

An eight-day chronometer takes about four half-turns daily

Having wound the chronometer, gently turn it over again, face up, being most careful to avoid any jerk or jar, and note that the dial on the face points to the '*up*' position.

Chronometer watches, deck watches, and pocket watches should be wound daily. Take care that when the winding knob is turned, the watch itself is kept motionless. Turning the watch in the opposite direction to the knob throws an unfair strain on the mechanism, and may cause serious damage.

When deck watches are being wound they should be held face downwards to assist the oil to percolate.

Setting the Hands. The hands of chronometers and chronometer watches must never be moved. The latter are fitted with mechanism enabling this to be done, but it should not be used.

The hands of deck watches and pocket watches may be re-set if necessary, but they must be turned forwards, never backwards, because this will damage their mechanism.

Most pocket watches and some deck watches are not fitted with separate push-pieces for setting the hands. Instead they have a special notification issued with them giving instructions for setting the hands.

COMPARING

A *Chronometer Comparison Book* (Form S.384) is supplied to assist the navigating officer and to ensure uniform procedure in H.M. ships. It is intended for three chronometers, and each book contains sufficient space for one year's comparisons.

Chronometers should be compared daily, and it is usual to do this immediately after winding them. Chronometers beat every half-second, but modern watches usually have a lever movement and beat five times a second. A few chronometer watches have a chronometer movement and beat five times in two seconds.

When about to compare the chronometers, open only the lid of 'A' chronometer, so that its tick may sound louder than the others.

Write down the time which 'A' chronometer is going to show—say $11^h\,31^m\,00^s$—and when the second hand gets to 50 seconds, start counting the beats thus: 'half', 'one', 'half', 'two', 'half', 'three' and so on. In a few moments the beat can easily be counted without looking at 'A' chronometer. Then, still counting the beats, look at the other chronometer and note exactly the reading of its second hand at the instant you hear 'A' beat the exact second decided on. The difference between the readings of the second hands will give the *comparison*. Repeat this procedure for the third chronometer and the deck watch.

An easy method of writing comparisons is to choose a whole minute on 'A' for comparing 'A' and 'B', the next half minute for comparing 'A' and 'C', the next whole minute for comparing 'A' and the deck watch. The entire process takes one minute.

An example of a complete page of comparisons is given inside the cover of the *Chronometer Comparison Book*.

Any alteration of the daily difference shows that the chronometer concerned is irregular.

If the daily difference of comparison between 'A' and 'B' remains constant, and that between 'A' and 'C' alters, it is probable that 'C' has altered its rate.

Chronometer errors should be shown as all fast or all slow on G.M.T., not some fast and some slow. With practice, chronometers can easily be compared to one quarter of a second. Accurate comparisons are most important when chronometers are rated.

All events likely to affect the running of the chronometers should be noted. It must be remembered that excessive movement of the ship, gun firing, rapid changes of temperature, etc., are liable to cause considerable variations in the observed rates.

Remember that even the best chronometers will not keep an absolutely unvarying rate for any length of time. Their rates, therefore, should be verified by any of the methods available.

TO FIND THE ERROR OF A CHRONOMETER

Whenever possible, comparisons of the chronometers with G.M.T. should be obtained at intervals not exceeding ten days.

The error of a chronometer can be found by means of :

1. wireless time signals.
2. chronometer-depot clock.
3. telegraphic time signals.
4. visual time signals.
5. astronomical observations.

Wireless Time Signals. Certain W/T stations send out time signals by various methods (*Rhythmic, Onogo,* etc.), details of which are given in the *Admiralty List of Wireless Signals.*

Before finding the error by this method, the navigating officer should inform the wireless office which time signal he requires. A possible error will be eliminated if he is able to go to the wireless office and use the headphones himself.

Chronometer-Depot Clock. To find the error by depot clock, the deck watch must be taken ashore to a chronometer depot and compared with the depot clock. By making a mean comparison as explained later, the error of the chronometer can be obtained.

Telegraphic Time Signals. The standard clock in every national observatory is regulated daily by observations taken with a transit instrument. This standard clock is connected with the telegraph system throughout the country, and at a certain hour each day a signal is transmitted to all telegraph offices. In the United Kingdom, the transmission is at 1000 G.M.T.

Visual Time Signals. At most important ports, a time signal is made to assist shipping and usually consists of the automatic release of a ball from the yardarm of a signal station. The existence of these stations is noted on the charts and in the *Sailing Directions.* Full details are given in the *Admiralty List of Lights.*

It must be remembered that the time required is the instant the ball *starts to fall.*

Astronomical Observations. The methods of obtaining the errors of chronometers from astronomical observations are described in Volume III. Owing to the advent of wireless, it is seldom necessary to use these methods.

To Find the Error of a Chronometer by Time Signal or by Depot Clock. Just before going to take the time signal, compare the D.W. with all three chronometers. Thus :

	h m s		h m s		h m s
D.W.T.	8 19 21·25	D.W.T.	8 19 56·5	D.W.T.	8 20 27
'A'	6 16 00·00	'B'	7 17 00·0	'C'	7 21 00
D.W. fast on 'A'	2 03 21·25	D.W. fast on 'B'	1 02 56·5	D.W. fast on 'C'	0 59 27

Having made this comparison, find the error of the D.W. on G.M.T. by the time signal. As soon as possible afterwards, again compare the D.W. with all three chronometers. Thus :

	h	m	s		h	m	s		h	m	s
D.W.T.	8	28	21·25	D.W.T.	8	28	56·5	D.W.T.	8	29	27
Error slow	1	19	16·00	Error slow	1	19	16·0	Error slow	1	19	16
G.M.T.	9	47	37·25	G.M.T.	9	48	12·5	G.M.T.	9	48	43
'A'	6	25	00·00	'B'	7	26	00·0	'C'	7	30	00
'A' slow on G.M.T.	3	22	37·25	'B' slow on G.M.T.	2	22	12·5	'C' slow on G.M.T.	2	18	43

Should the seconds shown by the D.W. differ in the first and second comparison, repeat the comparison and check the working.

THE RATE OF A CHRONOMETER

The difference between two errors of a chronometer divided by the time elapsed between finding them is called the *rate*. The time elapsed is called the *epoch*, expressed in days and decimals of a day.

The epoch should not exceed ten days or be less than five days. In practice, it is usual to take the errors of the chronometer every ten days as this simplifies the working.

The difference between two errors is called *the accumulated rate*.

$$\frac{\textit{accumulated rate}}{\textit{epoch}} = \textit{the daily rate}$$

Always work in days and decimals of a day (to 2 places). Reduce all times to G.M.T., and so avoid the difficulties that may occur when zone times are used or when the 'date line' is crossed.

MEAN COMPARISON

It is sometimes impossible to compare the D.W. and the chronometers immediately after the error of the former has been obtained, as, for instance, when an error has been obtained from the depot clock or by telegraph.

Suppose 'A' has a steady gaining rate of 3 seconds a day, and the D.W. a losing rate of 10 seconds a day. Clearly the comparison between them cannot remain constant even for one hour.

If the rates are steady, and comparisons are made before and after observing the error, it follows that by interpolation a comparison may be deduced which will be correct for any particular

instant between the two comparisons actually taken. This calculated comparison is called a mean comparison.

Example 1.

Before observing error		*After observing error*	
	h m s		h m s
D.W.T. ..	8 24 07	D.W.T. ..	10 25 10
'A' ..	8 39 00	'A' ..	10 40 00
D.W. fast on 'A' ..	11 45 07	D.W. fast on 'A' ..	11 45 10

The elapsed time between comparisons by the D.W. is $2^h\ 1^m\ 3^s$ or 121 minutes, approximately. Suppose that the D.W. showed $9^h\ 57^m\ 20^s$ when the W/T signal was received, and that it was made at 1145 G.M.T. :

	h m s
D.W.T. at which the error was observed ..	9 57 20
D.W.T. of last comparison	10 25 10
Elapsed time	27 50

In 121 minutes the D.W. has gained 3 seconds on 'A'.

In 27·8 minutes the D.W. has gained $\frac{27{\cdot}8 \times 3}{121} = 0^s{\cdot}7$ on 'A'.

By the last comparison the D.W. was $11^h\ 45^m\ 10^s$ fast on 'A'. Therefore at the time the error was observed the D.W. was $11^h\ 45^m\ 9^s{\cdot}3$ fast on 'A', and at the time the error was observed, 'A' was showing $10^h\ 12^m\ 10^s{\cdot}7$.

	h m s
G.M.T. at which error was observed	11 45 00·0
'A' showed, when error was observed	10 12 10·7
∴ 'A' is slow on G.M.T. at 1145.	1 32 49·3

Example 2. At 1300 G.M.T. on the 14th September at Gibraltar, the D.W. was 48^s fast on G.M.T.

		h m s
Comparison	'A' ..	12 39 00.0
	D.W. ..	1 05 15·2

At 0700 (Zone − 2) on the 21st September at Port Said, the D.W. was 17^s fast on G.M.T.

		h m s
Comparison	'A' ..	4 43 00·0
	D.W. ..	5 08 36·2

Find the rate of 'A'

At 1300 G.M.T. on the 14th September :

		h	m	s	
D.W.T.	..	13	05	15·2	
Error	..			48·0	—
G.M.T.	..	13	04	27·2	
'A'	..	12	39	00·0	
∴ 'A' is	..		25	27·2	slow on G.M.T.

At 0500 G.M.T. on the 21st September :

		h	m	s	
D.W.T.	..	5	08	36·2	
Error	..			17·0	—
G.M.T.	..	5	08	19·2	
'A'	..	4	43	00·0	
∴ 'A' is	..		25	19·2	slow on G.M.T.

Accumulated Rate = 8 seconds gained.
Epoch = 1300 G.M.T. 14th Sept. to 0500 G.M.T. 21st Sept.
= $6^d\ 16^h$
= $6^d{\cdot}67$

Rate $= \dfrac{8}{6{\cdot}67}$
= 1·2 seconds gaining.

THE DECK-WATCH ERROR AT ANY TIME

Since the deck watch is always used for taking times of sights, dropping a time ball, etc., it is most necessary to know its accurate error at any time.

This can be found by finding the error of each chronometer on G.M.T. at the time required, on the assumption that its rate has been constant since the last time signal was received. Then, from comparisons, the D.W. error on each chronometer can be obtained, giving three different D.W. errors on G.M.T. If these errors are approximately the same, the mean is taken as the actual error ; but if one differs from the other two, it shows that one chronometer is running irregularly, and the mean of the other two only should be taken.

The D.W. error obtained by applying the accumulated rate to the last error by time signal, should never be used.

Example. To find the deck-watch error before taking sights.

At 1000 G.M.T. on the 18th December, chronometers were found to have the following errors and rates by time signal:

	h m s		s
'A'	0 33 44	slow on G.M.T.	Rate 2·01 gaining
'B'	1 39 06	,, ,, ,,	,, 3·44 ,,
'C'	7 05 31	,, ,, ,,	,, 1·20 ,,

At about 0500 G.M.T. on the 20th December the following comparisons were made:

	h m s		h m s		h m s
'A'	4 28 00	'A'	4 28 30	'A'	4 29 00
'B'	3 22 36	'C'	9 56 41·5	D.W.	6 06 23

What deck-watch error should be used for sights taken immediately after the comparisons?

Last error obtained .. .. 18th December 1000
Error required .. .. 20th December 0500

Epoch .. .. .. 1^d 19^h or 1·79 days

	'A'	'B'	'C'
Epoch	1·79 days	1·79 days	1·79 days
Rate	2^s·01 gaining	3^s·44 gaining	1^s·20 gaining
Accumulated Rate ..	3^s·60 gained	6^s·16 gained	2^s·15 gained

	'A' h m s		'B' h m s		'C' h m s
Error on the 18th	0 33 44·00 slow		1 39 06·00 slow		7 05 31·00 slow
Error on the 20th	0 33 40·40 slow		1 38 59·84 slow		7 05 28·85 slow
'A'	4 29 00·00	'A'	4 28 00·00	'A'	4 28 30·00
D.W.	6 06 23·00	'B'	3 22 36·00	'C'	9 56 41·50
D.W. fast on 'A'	1 37 23·00	'B' fast on 'A'	10 54 36·00	'C' fast on 'A'	5 28 11·50
		D.W. fast on 'A'	1 37 23·00	D.W. fast on 'A'	1 37 23·00
		D.W. slow on 'B'	9 17 13·00	D.W. slow on 'C'	3 50 48·50
'A' slow on G.M.T.	0 33 40·40	'B' slow on G.M.T.	1 38 59·84	'C' slow on G.M.T.	7 05 28·85
D.W. fast on G.M.T.	1 03 42·60	D.W. slow on G.M.T.	10 56 12·84	D.W. slow on G.M.T.	10 56 17·35
		D.W. fast on G.M.T.	1 03 47·16	D.W. fast on G.M.T.	1 03 42·65

It is seen that the D.W. error derived from 'B' chronometer differs considerably from the other two. 'B' chronometer is therefore running irregularly and is discarded, the mean of the other two errors being used.

The D.W. error to be used, therefore, is 1^h 03^m 42^s·6 fast on G.M.T.

CHRONOMETERS AND WATCHES UNFIT FOR USE

Chronometer and Chronometer Watches are considered unfit for use when they :

1. are broken down or damaged.
2. have run for four years since the date of issue from the Royal Observatory. (The date is shown on the label placed inside the box.)
3. have a daily rate exceeding 6 seconds.
4. have an irregular daily rate.

Deck Watches are considered unfit for use when they :

1. are broken down or damaged.
2. have run for four years since the date of issue.
3. have a daily rate exceeding 20 seconds.
4. have an irregular daily rate.

Pocket Watches are considered unfit for use when they :

1. are broken down or damaged.
2. have run for six years since the date of issue from the Royal Observatory.
3. have an inconveniently large or unreliable rate during short intervals.

REPAIRS

If a chronometer or chronometer watch proves unreliable or becomes defective when the ship is abroad, it should be returned to the chart depot with a demand for a replacement. When the ship is in home waters, the instrument should be sent to the Royal Observatory, Greenwich.

Chronometers and chronometer watches should never be sent, either at home or abroad, to local watchmakers for repairs, adjustments, or starting.

To entrust these delicate and expensive instruments to inexperienced workmen usually does more harm than good, and except in grave urgency in foreign waters (in which event a special report of the circumstances is to be forwarded to the Hydrographer) the foregoing prohibition is to be strictly observed. Demands for replacements, if the ship is in home waters, are always to be forwarded to the Hydrographer.

Deck and pocket watches are never to be sent to a watchmaker for repair by ships in home waters, but on a foreign station, where there is no chronometer depot, they may be entrusted to good local watchmakers for minor repairs. In all other circumstances they are to be exchanged at the nearest chronometer depot if the ship is abroad, or returned to Greenwich if the ship is in home waters, replacements being demanded from the Hydrographer.

RETURNING CHRONOMETERS AND WATCHES

The date of issue from the Royal Observatory is always given in the lid of the box and on the supply note. When four years have elapsed from this date, the chronometers are to be exchanged for others. (Pocket watches are to be exchanged after six years from the date of issue.)

If a ship is abroad, this should be done on the first visit to a naval port where there is a chronometer depot.

If the ship is not likely to visit such a port soon after the chronometers or watches have become time-expired, application is to be made to the Hydrographer.

If the ship is in home waters, application is to be made to the Hydrographer.

When chronometers or watches are returned, they are to be accompanied by a supply note (S.383), and a receipt note (S.383) is to be obtained for them. If they are unreliable or damaged, a full report of the circumstances is to be sent at once to the Hydrographer, and a duplicate of this report is to be sent to the Royal Observatory or chart depot with the chronometer or watch. (K.R. & A.I., Articles 1194 (4) and 1193 (5).)

THE PACKING AND TRANSMISSION OF CHRONOMETERS

(See form H.112)

On several occasions chronometers have arrived at the Royal Observatory either ruined or badly damaged because of insecure packing. Great care should therefore be taken in packing and sending chronometers. The following instructions on this subject have been issued by the Astronomer Royal.

1. Take the brass case containing the chronometer out of its gimbals, unscrew the glass face, and remove the chronometer from the case. Secure the balance with two thin wedges of cork, placed as shown in figure 118. The wedges must be perfectly dry.

In order that the wedging action is divided between the cross bar and the arm of the balance, take care that the wedge, while being placed as close as possible to the cross bar, does not touch the brass screws carried at its extremity. The placing of the two wedges should be symmetrical about the axis of the balance, and although they must be inserted firmly enough to prevent any motion of the balance, no attempt should be made to force them further. Replace the chronometer in the brass case and screw on the glass face, but do not put it again in its gimbals. Take out the screws that fix the gimbal ring to the wooden box; wrap them in paper and include the circular brass nuts, if fitted; lay the packet at the bottom of the wooden box. Place a little stuffing, such as dry oakum, dry paper shavings, fine wood shavings, all thoroughly dry and free from dust, or any other dry, clean, and soft material, in the bottom of the

box. Lay the gimbal ring on the stuffing, and check that the screws and nuts in the gimbal ring, if any are used for fixing the chronometer to the ring, are screwed home. Put some more stuffing on the gimbal ring, and on top of this pack the brass case containing the chronometer, first wrapping a sheet of thin paper round it to prevent contact with the stuffing material. Fill the space between the brass case and the wooden box with stuffing.

2. Having closed the wooden chronometer box, put it in a wicker basket or hamper, packed with plenty of soft stuffing. If no wicker basket is available, a wooden box must be used. The box must be surrounded with a large quantity of stuffing and enclosed in canvas to avoid any jarring blow.

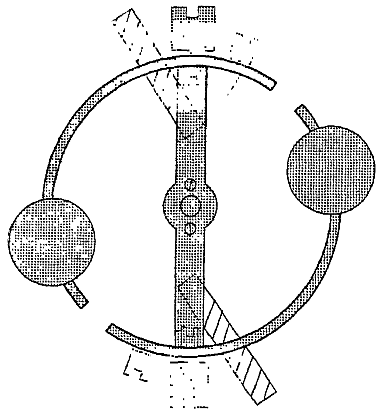


FIGURE 118.

It is most important that the outside of the packing case is soft and yielding. When using a wooden box, fix the lid of the box with screws.

To guard against the extraction of chronometers and watches from their hampers without removing the seals or cutting the cord, secure the lids by placing the cord over the centre of the lid and knotting it round the edge of the hamper. The parts should then be crossed and knotted again at short intervals so as to form a radiating web over the lid. Finally the ends should be sealed on a card which is tacked to the lid of the hamper.

With a long hamper containing two or more chronometers, two pieces of cord should be used and worked from the hinges, the ends of each cord being separately sealed as before, near the middle of the front of the hamper.

3. Two or more chronometers secured in their boxes in the way already described, may be packed in a case or basket, but all contact

between them must be prevented by using straw or some other stuffing material.

4. The package should be addressed to the Astronomer Royal, Royal Observatory, Greenwich, S.E.10, with the note 'Chronometers with care'. When sending from abroad, add to the address 'c/o Naval Store Officer, West India Docks, London', also name of the ship or route by which it goes to England. When sending from a port in the United Kingdom, state by which railway, and forward by mail or passenger train, *never by goods train.*

5. When chronometers are sent by steamship, cabin freight, if it can be arranged with the agent, should be obtained. The courtesy of the captain in command of mail steamers will frequently permit the placing of packages of chronometers in the mail room for greater safety; but chronometers are never to be shipped as mails, because not only is full postage by weight charged, but the package may be treated as a bag of letters and receive injury.

6. When a package is sent to the Astronomer Royal, a note should be made on the outside, saying where it comes from, and a letter should be sent by separate post to the Astronomer Royal giving information about the contents of the package, with the makers' names and numbers of the chronometers and the route by which they have been sent.

THE PACKING AND TRANSMISSION OF WATCHES

Chronometer watches, deck watches and pocket watches may be sent by post if properly packed.

In packing watches, the balance must be wedged, and to do this the back of the watch must be opened. The back of the watch may be of two types.

1. Most chronometer and deck watches have an outer and inner back, both opening on hinges. A few pocket watches also have these fittings.

2. The back of most pocket watches is removed by unscrewing it bodily. A few chronometer and deck watches also have this fitting.

A special notification is issued with all watches with this fitting.

Before the wedging is done, it is advisable to let the watch run down.

To Wedge the Balance. Open the back of the watch, and draw through the balance wheel a narrow tapering strip of thin dry paper, as shown in figure 119.

The strip should be passed over the rims of the balance, and underneath the cross bar. This requires considerable care, and it is advisable to use tweezers. The ends of the strip should be secured by snapping the inner back of the watch on to them.

When the balances of watches with screw-on backs are wedged, the strip must be cut off at each end, after insertion, and care

must be taken to ensure that these ends are clear of the screw thread, because if they should become jammed in it when the back of the case is screwed on, considerable strain may be brought upon the balance and cause it to be damaged. The friction of the paper is sufficient to keep the balance at rest.

When the balance has been secured the watch is to be placed in its wooden case, and it should be covered with thin paper if there is any play.

The case containing the watch is then to be placed in a strong cardboard or wooden box and well packed with soft material to prevent it being injured by jarring. If a wooden box is used the lid must be fixed with screws.

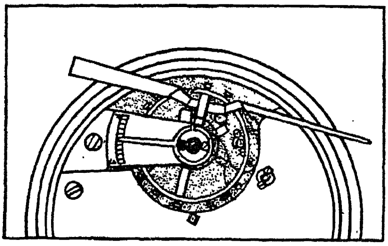


FIGURE 119.

The package is then to be sealed and addressed to the Astronomer Royal, Royal Observatory, Greenwich, S.E.10, and sent by post (registered parcel post when sent from a port in the United Kingdom), unless there happens to be a safer and more convenient way of sending it. Two or more watches may be enclosed in the same package if all contact between them is prevented by sufficient packing, and also if the postal limits are not exceeded.

The outside wrapper is to show clearly from which ship the package is sent, and both the Astronomer Royal and the Hydrographer are to be informed of its despatch.

TRANSFERRING CHRONOMETERS

Should chronometers or watches be transferred to another ship, supply and receipt notes (S. 383) should be sent with them and the Hydrographer immediately informed of the transaction on form S.379.

On the supersession of the navigating officer, a supply note is to be given to the relieving officer, who is to give a receipt note to the officer who is being relieved. A return on form S.379, accompanied by all receipt notes held by the officer who is being relieved, is to be forwarded to the Hydrographer immediately.

Form S.379 is, in addition, to be rendered annually on the 31st December and is to be accompanied by all receipt notes for the period since it was last forwarded.

LIST OF FORMS

H.110. Establishment of chronometers and watches for H.M. ships and vessels.

H.112. On the supply, use and treatment of chronometers, chronometer watches, deck watches and pocket watches.

S.379. Return of chronometers and watches on board and receipts and issues.
Rendered : 1. Annually.
2. On transferring chronometers.
3. On commissioning.
4. On paying off.

S.383. Supply and receipt note for chronometers and watches. When S.383 is rendered as a receipt note, the columns concerning error and rate need not be filled in.

S.384. *Daily Comparisons and Errors of Chronometers.* It is important that a complete record is kept of all chronometers and watches on page 9.

SYSTEM OF TIME-KEEPING AT SEA BY MEANS OF TIME ZONES

The adoption of this system ensures that all vessels using it will, when within certain defined limits of longitude, normally keep the same time in the same way that London, Plymouth, and Dover all keep the same time instead of the local time of each place.

The world is considered as being longitudinally divided into 24 zones each of 15° ; the centre zone lies between the meridian of 7½°E. and that of 7½°W., and is described as zone 0 ; the zones lying to the eastward are numbered in sequence from 1 to 12 with a minus (—) prefix, those to the westward being similarly numbered but with a plus (+) prefix ; the 12th zone is divided centrally by the 180th meridian (the date line), and the prefixes minus (—) and plus (+) are used in the eastern and western halves respectively. In the neighbourhood of land the boundaries between zones are modified so as to agree with the boundaries of the countries or areas using corresponding times.

The division of the World into zones is shown :

1. on Miscellaneous Chart 86.
2. on Chart 5006.
3. inside the back cover of this Volume.

The system is so devised that the zone is always a whole number of hours fast or slow on Greenwich. Each zone is denoted by a positive or negative number as follows :

Greenwich Mean Time is denoted by the number 0 or the word *zero*. A time fast on G.M.T. is denoted by a number with a minus prefix, equal to the number of hours that must be subtracted from Z.T. to obtain G.M.T. A time slow on G.M.T. is denoted by a

number with a plus prefix equal to the number of hours that must be added to Z.T. to obtain G.M.T. The number and its prefix together are known as the *zone description* of the time.

The time kept by any ship depends, if she is not in the open sea, on local orders and arrangements.

If the vessel is in the open sea, the time kept is determined by the zone in which the ship is steaming.

The zone description will not be the same as the number of the zone during the brief interval that elapses between the moment when a vessel crosses the boundary between two zones and the moment when she subsequently alters her clocks. If, however, the *zone description* is stated, there will be no confusion about times.

The Date or Calendar Line is a modification of the line of the 180th meridian, which is drawn so as to include islands of any one group on the same side of the line.

Full details of the date line are given on the Admiralty Time Zone Chart No. 5006, a copy of which is given at the end of this Volume.

When the ' date line ' is crossed on an easterly course the date is put back a day ; on a westerly course the date is put on a day.

Example. Ship Steaming West. Consider a ship steaming from Vancouver to Sydney and arriving on the date line at 1345 on the 2nd June, a Tuesday. She passes from Zone (+12) to Zone (—12).

At the instant she leaves Zone (+12), her Greenwich Date is :

Z.T.	1345 Tuesday, 2nd June
Zone	+12
G.D.	0145 Wednesday, 3rd June

If she makes no adjustment of one day, her Greenwich Date at the instant she enters Zone (—12) is :

Z.T.	1345 Tuesday, 2nd June
Zone	—12
G.D.	0145 Tuesday, 2nd June

She is therefore a day out on Greenwich time, and in order to bring herself into step again she must call her zone time 1345 (— 12) Wednesday, 3rd June, so that :

Z.T.	1345 Wednesday, 3rd June
Zone	—12
G.D.	0145 Wednesday, 3rd June

That is, she drops a day, and this she would probably do by keeping the time of Zone (+12) until midnight on Tuesday and then calling the next day Thursday in Zone (—12). If the example is worked with the ship steaming east, it is seen that she must repeat a day.

H.M. Ships are to Observe the Following Rules.

1. When a ship passes from one zone to another, the alteration of the ship's clocks other than signal clocks will be made as ordered by the Captain.

When clocks have to be advanced, the usual procedure is to advance the ship's clocks 20 *minutes* when they show 2230, 0230 and 0430.

When clocks have to be retarded, it is usual to put back the ship's clocks 30 *minutes* when they show 1730 and 1930.

2. Signal clocks should be *altered the full hour* at or near the actual time of passing from one zone to another. The zone description of the time kept by these clocks should be marked by a conspicuous label or attachment in some form which can readily be altered as required.

3. In all official correspondence when time is referred to, the zone description—at Z.T. 1654 (− 9), for example—is to be added.

4. When a ship is in harbour, or within the territorial limits of a country where the legal time differs half an hour from an exact zone time, the zone description with the hours and half hours is to be given. In a harbour where the legal time of the country is not in agreement with the zone system in any form, the exact amount in hours, minutes and seconds by which it differs from Greenwich Mean Time is always to be given together with its appropriate sign of (+) or minus (−).

SUMMER TIME

Many countries adjust their clocks during the summer months so that ' noon ' for domestic purposes is 1100, and an extra hour of daylight is added to the so-called evening.

To do this clocks are advanced a certain amount on zone time in the spring and put back to zone time in the autumn.

British Summer Time. (B.S.T.) Summer time in Great Britain normally begins at 0200 G.M.T. on the day following the 3rd Saturday in April (or if that day is Easter day, from the day following the second Saturday in April) and finishes on the day following the first Saturday in October.

If a ship in home waters is keeping B.S.T., the zone description of the time is (− 1).

All volumes of the *Admiralty List of Lights and Visual Time Signals,* and the *Admiralty List of Wireless Signals,* also the *Nautical Almanac,* include a complete table, headed ' Uniform Time System ', which gives the standard times kept in various parts of the world.

This information can also be obtained from the various time zone charts already mentioned.

Examples of the Zone System. When times of arrival and departure from places keeping different zone times are worked out, the best plan is to reduce the times to G.M.T. and thus avoid any chance of confusion, particularly when the date line is crossed.

Example 1. A ship at San Francisco (California) is ordered to arrive at Hakodate (Japan) at noon on the 20th January. She expects to make good a speed of 15 knots and proposes to allow 6 hours in hand for bad weather.

On what day and at what time should she sail from San Francisco?

San Francisco keeps Zone + 8.
Hakodate keeps Zone − 9.
San Francisco to Hakodate = 4,245 miles (from the *Admiralty Distance Tables* or *Ocean Passages of the World*)

Time taken on passage at 15 knots	$= \frac{4,245}{15} =$ 283 hours
Allowance for weather	6 hours
Total time steaming from San Francisco to Hakodate	289 hours
(equivalent to)	12 days 1 hour
Zone Time of arrival Hakodate ..	1200 (− 9) 20th Jan.
Zone correction	9
G.M.T. of arrival at Hakodate ..	0300 (G.M.T.) 20th Jan.
∴ G.M.T. of departure from San Francisco	0200 (G.M.T.) 8th Jan.
Zone correction	8
∴ Zone Time of departure from San Francisco	1800 (+ 8) 7th Jan.

Example 2. A ship at Dover proposes to sail for Rotterdam (Netherlands) at noon on the 1st June. She expects to make good 10 knots and does not propose to make any allowance for bad weather, and the tidal streams are expected to cancel.

What will be her expected time of arrival at Rotterdam?

Time kept at Dover ..	B.S.T. (Zone − 1)
Time kept at Rotterdam	− 20 minutes

NOTE. The Netherlands do not keep zone time but use the standard time of the meridian of Amsterdam, which is approximately 20 minutes east of Greenwich.

Dover to Rotterdam	130 miles (From the *Admiralty Distance Tables*)
Time on passage at 10 knots ..	$\frac{130}{10}$
(equivalent to)	13 hours
Zone time of departure from Dover	1200 (— 1) 1st June
Zone — 1	1
G.M.T. of departure from Dover	1100 (G.M.T.) 1st June
Time on passage at 10 knots ..	13
G.M.T. of arrival at Rotterdam ..	0000 (G.M.T.) 2nd June
Time correction	20
Standard time of arrival at Rotterdam	0020 (— 20 minutes) 2nd June

CHAPTER XII

TIDES AND TIDAL STREAMS

TIDAL DEFINITIONS

Tides are periodic vertical movements of the water on the Earth's surface.

Tidal Streams are periodic horizontal movements of the water that result from the tides.

Chart Datum is the level below which depths are given on the chart. At the International Hydrographic Conference 1926, the

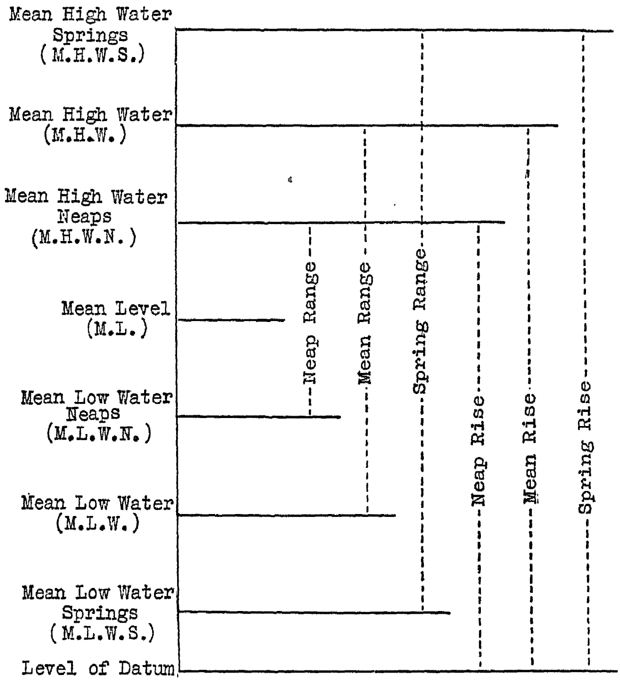


FIGURE 120.

nations represented agreed, subject to certain qualifications by the United States of America, that '. . . chart datum should be a plane so low that the tide will but seldom fall below it'.

This standard datum has not yet been fully adopted, and widely different datums remain in use.

All datums must be considered approximate because they are frequently fixed before tidal observations have been obtained and

analysed. The datum used is quoted on each Admiralty chart. On charts of small scale it is given in general terms, but on large-scale plans of harbours, etc., it is given to the nearest foot, thus: '*Soundings in feet* (*or other unit*). *Reduced* 3 *feet below* (*or above*) *Mean Low Water Springs* (*or other datum*).' Particulars of datums and tide levels at standard ports are also given in special tables in Part I of the *Tide Tables*.

The Height of the tide is the vertical distance at any moment between the water level and the chart datum. To measure the height of any particular tide, a datum must be chosen from the level of which measurements can be made. In order that Admiralty charts may show the least depth of water under ordinary conditions, the level chosen is approximately that of the lowest level to which the tide ordinarily falls.

In certain extreme circumstances the tide may fall appreciably below datum. When Admiralty charts depend on the surveys of other nations, the datum used is that of the original chart, and this may be appreciable higher or lower than that ordinarily used. If the height of the tide above datum is calculated for any particular time, it has only to be added to the charted depth of water to give the depth at that time. If the height is negative it must be subtracted from the depth.

The Rise of the tide is the height of high water.

The Range of the tide is the difference between the height of high water and the next succeeding or last preceding low water.

Mean High Water Springs (M.H.W.S.) and Mean High Water Neaps (M.H.W.N.) are the average heights of high water at springs and neaps, taken over a long period.

Mean Low Water Springs (M.L.W.S.) and Mean Low Water Neaps (M.L.W.N.) are the average heights of low water at springs and neaps, taken over a long period.

Mean High Water (M.H.W.) and Mean Low Water (M.L.W.) are the average heights of high and low water, taken over a long period.

Mean (or Half) Tide Level (M.T.L.) is the mean between the levels of M.H.W. and M.L.W. These levels require for their computation a long series of observations which has not always been obtained, and **Mean Level (M.L.)** as given in Part II of the *Tide Tables* is the best value of M.T.L. obtainable.

Mean Sea Level (M.S.L.) is the average level of the sea calculated from a long series of observations obtained at equal intervals of time.

Mean Spring Range and Mean Neap Range are the differences between M.H.W.S. and M.L.W.S., and M.H.W.N. and M.L.W.N. respectively.

Mean Range is the difference between M.H.W. and M.L.W.

Mean Spring Rise and Mean Neap Rise are the heights of M.H.W.S. and M.H.W.N.

Mean Rise is the height of M.H.W.

The Stand of the Tide is the period at high water between the tide's ceasing to rise and starting to fall. A similar stand of the tide occurs at low water.

The Time of High Water is the moment midway between the time at which the water ceases to rise and that at which it begins to fall. The time of low water is defined in a similar way.

Standard Ports are those ports for which predictions of the standard times and heights of H.W. and L.W. are published. These predictions, which are given in Part I of the *Tide Tables,* are made with the greatest possible accuracy.

Secondary Ports are those ports for which tidal differences and ratios on a standard port are published.

THE CAUSE OF TIDES

The theory and prediction of tides and tidal streams is fully described in the *Admiralty Manual of Tides.* In this chapter certain assumptions are made which, though not strictly true, nevertheless permit a simple and sufficient explanation to be given.

The Earth and Moon revolve in equilibrium, once a month, round their common centre of gravity which is situated inside the Earth's surface.

This motion, in so much as it is unaffected by other forces, is steady because the total gravitational attraction tending to draw the Moon and Earth together is exactly balanced by the total centrifugal force tending to force them apart.

At the Earth's centre the centrifugal and gravitational forces are equal and opposite, but elsewhere there is a residual force acting either towards or away from the Moon, and this force is called the *lunar tide-generating force.*

A similar argument holds when the inter-action between the Sun and the Earth is considered, but the *solar tide-generating force* is only about 3/7ths of the lunar on account of the greater distance of the Sun from the Earth.

The tide-generating forces act on every particle of the Earth, but only the water is free to move. Thus, on the side of the Earth nearer the Sun or Moon, attraction overbalances centrifugal force and the water tends to pile up and cause a high water at A, as shown in figure 121. On the opposite side of the Earth, centrifugal force overbalances attraction and tends to cause another high water at B. Along the meridian PP′ the tendency is for low water to be caused.

The effect of these tide-generating forces is to cause the water on the Earth's surface to take a form which is approximately elliptical in section, as shown in one particular circumstance by figure 121. The Earth's revolution about the Sun and its daily

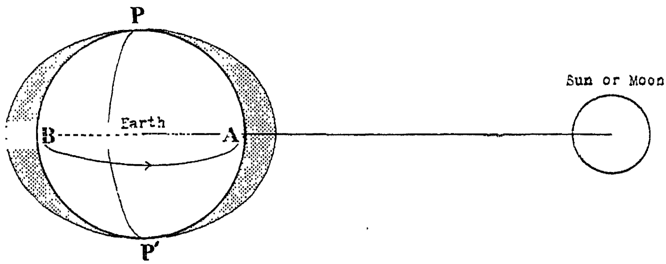


FIGURE 121.

rotation on its axis, however, bring about considerable and varying departures from the shape indicated in this figure because they give rise to periodic variations in the tide-generating force.

THE EFFECT OF THE EARTH'S ROTATION

Relative to the Sun, the Earth makes one complete revolution about its axis in an average time of 24 hours, and during this period the foregoing theory indicates that every place except the poles, if the Sun's declination is zero, experiences two high and two low waters. The interval between successive high waters due to the solar tide-generating force is thus, on the average, 12 hours.

Relative to the Moon, however, the Earth makes one complete revolution about its axis in an average time of 24 hours 50 minutes, and the interval between successive high waters due to the lunar tide-generating force is thus, on the average, 12 hours 25 minutes.

The distances of the Moon and Sun from the Earth are not constant because the orbits of the Moon round the Earth and the Earth round the Sun are elliptical, as shown in figure 122. Moreover the declinations of the Sun and Moon are always changing.

NOTE. When nearest the Sun the Earth is said to be in *perihelion*, and when farthest away in *aphelion*. When nearest the Earth the Moon is said to be in *perigee*, and when farthest away in *apogee*.

These changes, which are regular and periodic, effect both the magnitude and period of the tide-generating forces, and similar variations are therefore found in the actual tides.

1. *Variations caused by the daily alteration of the distance of the Earth from the Moon and the Sun.* When the Moon is nearest the Earth, the tide-generating force is greater than it is when the Moon is farthest away. At some position between the two this force will have its average value. The importance of this fact

will be appreciated when the prediction of tides is explained later in this Chapter.

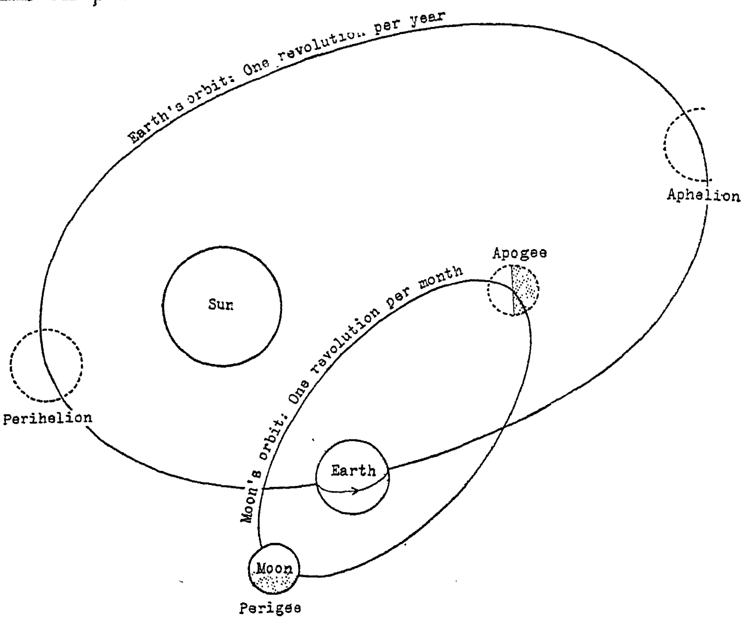


FIGURE 122.

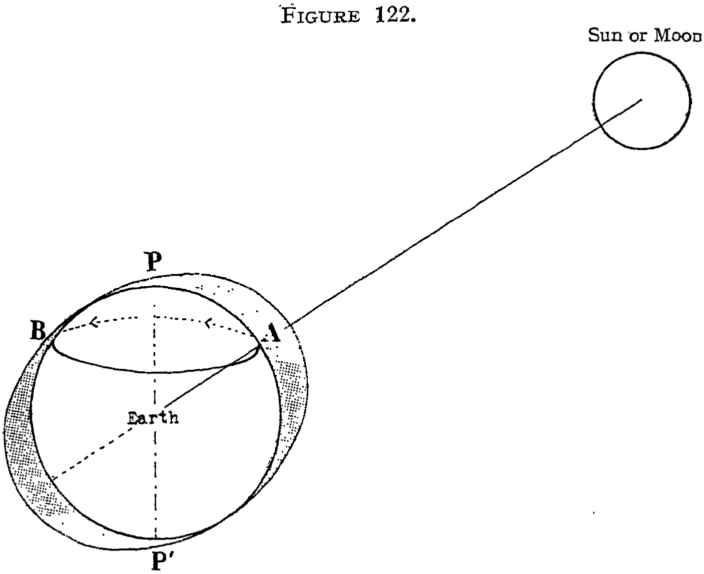


FIGURE 123.

The Sun's tide-generating force also has an average value, arrived at in a similar way.

2. *Variations caused by the changing declination of the Moon and Sun.* The Moon and Sun do not remain in the plane of the

equator. The Moon's declination changes during a lunar month in exactly the same way that the Sun's declination changes during a year.

The effect on the tides is twofold in that it produces (*a*) a diurnal inequality of *heights*, and (*b*) a variation in the *range* itself, independent of diurnal inequality.

(*a*) Figure 123 shows the Sun or the Moon causing a high water at a place A. Before experiencing another high water, A moves to a position B where the rise of the tide is less than at A. Clearly this inequality in the *heights* of the two tides does not occur when the Sun or the Moon has no declination, as shown in figure 121, and attains its greatest value when the Sun or the Moon has its greatest declination.

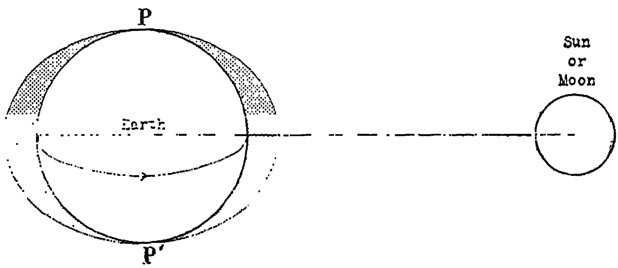


FIGURE 124.

(*b*) Figures 124 and 125 show the effect upon the *range* for particular values of the declination. In figure 124, the Sun or the Moon has no declination, and the *range* of the tide at any place does not alter. It has its greatest value on the equator, and it is zero at the pole. Figure 125 shows the Sun or the Moon with a hypothetical declination of 90°, thereby causing a permanent high water at the pole and a permanent low water at the equator. There is thus no tide anywhere, and once again the *range* does not alter, being zero. As the declination changes from 0° to 90°, the range must decrease from its maximum value to zero.

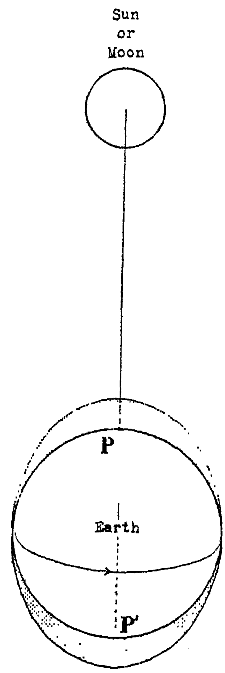


FIGURE 125.

Changes in the range of the tide are therefore to be expected with changes in the Sun's declination and in the Moon's, and the range at any place is greatest, so far as the Sun is concerned, when the Sun's declination is zero, and least when the Sun's declination is greatest. Similarly with the Moon.

The Combination of the Lunar and Solar Tide-Generating Forces. The Moon revolves round the Earth once in every month of roughly 29½ days, and the Earth takes 365¼ days to complete its revolution round the Sun, so that approximately every 29½ days the Moon

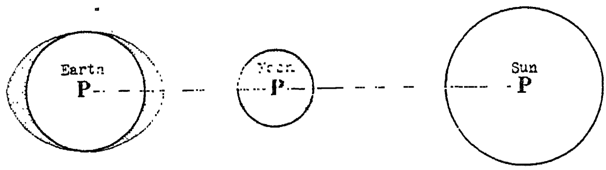


FIGURE 126.

passes once between the Sun and the Earth as shown in figure 126 When this occurs the Sun and Moon are said to be acting in *conjunction.*

Approximately 15 days later the Earth will be between the Sun and Moon, as shown in figure 127. When this occurs the Sun and Moon are said to be acting in *opposition.*

On both these occasions the lunar and solar tide-generating forces are acting in the same direction. That is, if the lunar and solar waves were to exist separately, the crests of the two undulations would pass a certain meridian simultaneously and the height of the tide would be the sum of the heights of the two crests.

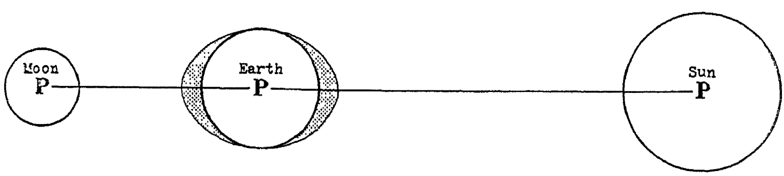


FIGURE 127.

It is thus natural to expect that twice in a lunar month tides will be of greater magnitude than at any other time during the month. These expectations are, in fact, realised, and although other inequalities supervene and may result, at some places, in the occurence of these tides at times other than those which the foregoing argument suggests, on the greater part of the Earth they occur about the time of new and full Moon and are called *Spring Tides.* Spring tides can be defined, therefore, as those tides which twice in a lunar month rise highest and fall lowest from the mean evel and occur at about the time of new and full Moon.

Between opposition and conjunction the Moon will, twice during a lunar month, exert its tide-raising force at right angles to that of the Sun, as shown in figure 128. It is then said to be in *quadrature*.

When this occurs it is seen, from figure 128, that the ~~lunar and~~ solar tide-generating forces are acting at right angles to each other. That is, the crest of one undulation passes a certain meridian at the same time as the trough of the other undulation. It is thus natural to expect that twice in a lunar month tides will be

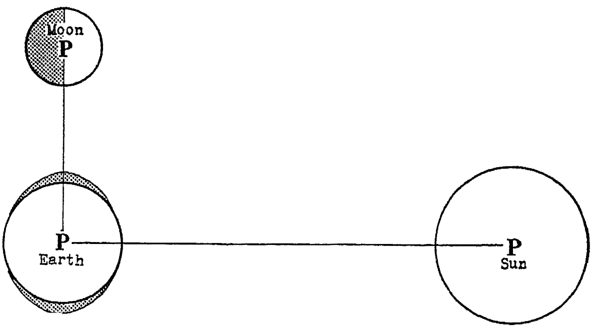


FIGURE 128.

experienced of less magnitude than those experienced at any other time during the month.

These expectations are again realised, and although inequalities similar to those that influence spring tides may supervene, on the greater part of the Earth tides of small range occur about seven days from new and full Moon and are called *Neap Tides*. Neap tides can be defined, therefore, as those tides which twice in a lunar month rise least and fall least from mean level and occur at about the times of the first and last quarters of the Moon.

TIDAL PREDICTION

It has been shown, in elementary theory, how the tendency is for a high tide to be caused on both sides of the Earth, approximately under the Moon. (Directly under the Moon at new and full Moon.)

This *theoretical* or *equilibrium* tide tends to take the form of a progressive wave. Its progress is, however, impeded by a number of factors such as friction of the Earth's surface, the land dividing the oceans, depths of the sea, wind and current, with the result that the equilibrium tide does not exist in actual fact. It is, however, known that the actual tide at any place models itself closely on the equilibrium tide; that is, it is largely formed by the same constituents.

In order to predict the height of the tide at any place with accuracy, extensive tidal observations must be carried out

and the result analysed. For the purpose of this analysis, the terrestrial wave is assumed to be formed by a number of simple harmonic constituents—hence the name, harmonic tidal analysis—and of these terrestrial constituents the two most important are:

1. *The principal lunar semi-diurnal constituent.* This is the tide which theory indicates would be formed by an ideal Moon moving uniformly in a circular orbit in the plane of the equator at the average speed of the real Moon in its orbit. Its amplitude is that of the theoretical tide caused by the Moon about half-way between perigee and apogee when at average northerly or southerly declination. This constituent is referred to by the symbol M_2.

2. *The principal solar semi-diurnal constituent.* This is the tide which theory indicates would be formed by an ideal Sun moving uniformly in a circular orbit in the plane of the equator at the speed of the Mean Sun. Its amplitude is that of the theoretical tide caused by the actual Sun about half-way between perihelion and aphelion when at average northerly or southerly declination. This constituent is referred to by the symbol S_2.

Each of the other constituents introduces one of the different factors, such as parallax and declination, which alter the tide-generating forces.

The periods and phases of these equilibrium constituents can be calculated, for any given time, from the known movements of the Earth and Moon relative to the Sun.

For convenience these constituents are called diurnal or semi-diurnal according as their periods are approximately 24^h or 12^h. Each constituent is distinguished by a capital letter with a numerical suffix which indicates, approximately, the number of times each day that the high water caused by the constituent occurs.

Every terrestrial constituent lags behind its corresponding equilibrium constituent, and its amplitude is not that of the equilibrium constituent. It can, however, be defined by:

1. g, its phase lag, adjusted to the standard time kept at the place.
2. H, its amplitude.

Since it is more convenient to compute in angle than in time, g is invariably given as an angle. Any constituent represents an oscillation about mean sea-level, the surface being raised to its greatest extent (high water) when the phase is 0°, and depressed to its greatest extent (low water) when the phase is 180°. When the phases are 90° and 270° the elevation is zero. If g were converted to hours and minutes, it would be the difference between the time of high (or low) water resulting from the equilibrium constituent and that resulting from the terrestrial. The amount of this raising or depressing is called the amplitude, and denoted by H.

The phases of the equilibrium constituents at 0^h on the 1st January of each year have been computed for many years in

advance, and are published in a number of works of reference. From the phase of a constituent at 0^h on the 1st January, and its known period, its phase at any hour on any day may be computed, and if E is the phase of the equilibrium constituent at any time, then :

(*a*) the height of the constituent at the place at any time (referred to mean sea-level) is equal to H cos $(E - g)$.

(*b*) the height of the tide is the sum of the values of H cos $(E - g)$ for all the constituents at the place.

The values of g and H for the various constituents are called the *harmonic constants* for the place and are published for the more important constituents in Part II of the *Admiralty Tide Tables.*

METHODS OF PREDICTING TIDES IN THEIR ORDER OF ACCURACY

1. The harmonic method.
2. The Admiralty method.
3. Tidal differences and ratios.
4. *The Co-tidal Chart of the British Isles and Adjacent Waters,* for places in the open sea in the vicinity of the British Isles.
5. Non-harmonic constants given on the chart.

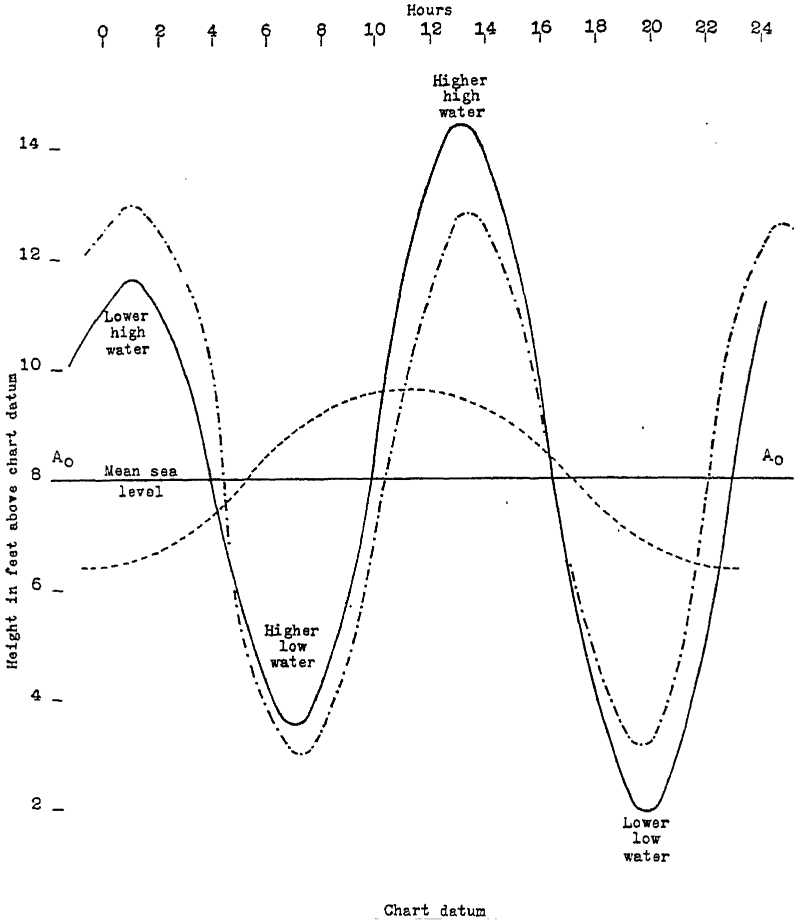
THE HARMONIC METHOD OF PREDICTION

A brief explanation of the principles on which this method is based has already been given. The number of harmonic constituents is great, and the labour of predicting by their means, especially without mechanical assistance, is so considerable that this method is impracticable for seamen, but the actual times and heights of high water and low water at the standard ports, given in Part I of the *Tide Tables,* are worked out by this method.

The four main harmonic constituents, which will be referred to when the Admiralty method of predicting tides is considered, are the principal lunar and solar semi-diurnal constituents M_2 and S_2, and two constituents that introduce the inequalities in the heights of successive high and low waters which theory indicates should occur when the declinations of the Sun and Moon are not zero.

A comparison between the state of affairs when these inequalities exist and when they do not, should make it apparent that the tendency is for the height of one high water to be raised the same amount as the height of the succeeding one is diminished. The necessary modifications to the simple harmonic waves M_2 and S_2 can therefore be accomplished by imposing on them constituents having periods approximately twice as great ; for if the crest of such a wave were made to coincide with the crest of the M_2 or S_2 constituent, its trough would coincide with the next M_2 or S_2 crest. This is, in fact, the method adopted to introduce these inequalities and, since the periods of these constituent waves are approximately twice those of the M_2 and S_2 waves (that is, about 24 hours as opposed

to about 12 hours), they are called *diurnal constituents* and the inequalities they introduce *diurnal inequalities.* They are simple



---------- Any diurnal constituent

-.-.-.-.- Any semi-diurnal constituent

———— Combined effect of diurnal and semi-diurnal constituents showing how a higher and lower H.W. and L.W. are caused.

FIGURE 129.

harmonic waves, and if they did actually exist by themselves they would produce a tide in which only one high and one low water would be experienced during the course of a day.

These diurnal constituents are denoted by the symbols K_1 (a luni-solar declinational constituent) and O_1 (a lunar declinational constituent).

Figure 129 shows the effect of imposing a diurnal constituent on a semi-diurnal constituent.

The various terrestrial effects which tend to alter the shape of the tidal wave are allowed for by the same system; that is, by introducing a number of other constituents.

At some places, the diurnal inequalities are so large that only one high water occurs each day. The tides so formed are called *Single Day Tides.*

THE ADMIRALTY METHOD OF PREDICTING TIDES

The Admiralty method of predicting tides at secondary ports is more accurate than any method of approximate prediction hitherto available. It is not to be expected that its accuracy equals that aimed at in Part I of the *Tide Tables,* where predictions are made by harmonic methods, but the predictions may always be relied on to fulfil the requirements of navigation.

As full instructions for predicting tides and tidal streams by this method and for analysing short periods of observations, together with tables to assist prediction and analysis, are given in Part III of the *Tide Tables,* only a brief summary of the method is given in this Volume.

The four principal harmonic constituents, M_2, S_2, K_1, and O_1, are used, and prediction is made in three successive stages.

1st Stage. Modifying the constituents for the astronomical positions of the Moon and Sun on the day of prediction by Table I, 2(a) and 2(b).

2nd Stage. Combining these modified constituents into two—a composite semi-diurnal constituent and a composite diurnal constituent—by means of Table 3.

3rd Stage. Combining the composite semi-diurnal and diurnal constituents by Table 4 and obtaining the approximate times and heights of high and low water.

NOTE. (*a*) It may also be necessary to correct the prediction for the effect of shallow water.

(*b*) Standard time in degrees is converted to standard time in hours between stages two and three.

(*c*) On completing the first stage, prediction for height at a definite time can be obtained by following the methods shown on Form B. (Form B will be referred to later in the Chapter.)

The height of the tide, as predicted in this way, is referred to mean sea-level, but the soundings on the charts are usually referred to a low-water datum. When the depth of water is found, the height of mean sea-level above chart datum, which is given in Part II of the *Tide Tables* in the column headed A_0, must therefore

be applied to the predicted height in order to find the height with reference to chart datum. The resulting height must then be applied to the charted depth. This step is allowed for in the design of Forms A and B, which are referred to later in the Chapter.

This method provides predictions of progressive degrees of accuracy according to individual requirements. If the amplitude of the diurnal tide found at stage (2) is not more than 1/20 of the semi-diurnal tide, it can be neglected, because it will have little or no effect.

The method is also arranged to give the height of the tide for a short period either side of any required time.

Predictions by the Admiralty method are reliable in all circumstances, but, though special provision is made for abnormal shallow-water constituents, the accuracy attained may be lower than usual when these are very large.

The way in which this method predicts tidal streams is described in Part III of the *Tide Tables*.

Forms for Predicting by the Admiralty Method. H.M. ships are supplied with special forms to be used when predicting by this method.

Form A, for finding the times and heights of high and low water.

Form B, for finding the height of the tide at any given time.

The forms are self-explanatory and so arranged that it is a simple matter to use them. Examples of worked forms are given on pages 26 to 28 of Part III of the *Tide Tables*.

TIDAL DIFFERENCES AND RATIOS

Tidal differences are quantities in units of time which, when applied to the predicted standard time of H.W. or L.W. at a standard port, give approximately the corresponding standard time of H.W. and L.W. at the secondary port.

If the standard time kept at the standard port differs from the standard time kept at the secondary port, the necessary adjustment is embodied in the ‘ differences ’.

Ratio of ranges is the ratio of the range of the tide at a secondary port to the range at a standard port. The height of the tide above or below mean sea-level at the standard port multiplied by the ratio of ranges gives the height of the tide above or below mean sea-level at the secondary port.

The ratio of ranges is given only when the datum at the secondary port is not the same as the datum at the standard port. When the same datum is used at both ports, the ratio of rises is given.

Ratio of rises is the ratio which the rise of the tide at a secondary port bears to the rise of the tide at a standard port. The relation between the rise at springs and the rise at neaps is not the same at all places. Where only one is known, neap rise can be taken to be spring rise multiplied by 0·8.

Tidal differences and ratios are given in Part II of the *Tide Tables* for certain places where the tide is entirely, or nearly, semi-diurnal. The accuracy of predictions thus obtained will be correct to within half an hour and 1/10th of the range.

A full description of the way of working the method is given in Part III of the *Tide Tables* on page 27.

This method should be regarded as subsidiary to the Admiralty method and should be used only when approximations are required within the above limits. The errors stated may be exceeded near the limits of areas for which differences are given.

NON-HARMONIC CONSTANTS

Non-harmonic constants are given on the charts, but not in the *Tide Tables*, and are intended for use when *Tide Tables* are not available. They are given only at places where the tide is entirely, or nearly, semi-diurnal. Predictions computed from them must always be regarded as approximate and liable to considerable error, and used accordingly.

Caution. Changes in the practice of using non-harmonic constants have occurred of late years. The number of Admiralty charts is very great and much time is required for complete revision. Non-harmonic constants are consequently still to be found on some of the older charts of regions where the type of tide is such that they should not be used. Generally, but not always, they are accompanied by a cautionary note.

The non-harmonic constants given on the Admiralty charts are:

1. *Mean High Water Lunitidal Interval* (*M.H.W.I.*). The interval between the Moon's transit at Greenwich and the next following high water of the semi-diurnal tide, is called the high water lunitidal interval. Owing to the solar tide, and to the effects of changes in the parallax and declinations of the Moon and Sun, the lunitidal interval is not constant.

The mean high water lunitidal interval is the average from a long series of observations.

2. *Mean Spring Rise.* Is the height of mean high water springs.
3. *Mean Neap Rise.* Is the height of mean high water neaps.

NOTE. Many of the older charts give the lunitidal intervals at full and change of the Moon (H.W.F. & C. and L.W.F. & C.) in place of the mean intervals. These intervals have not been adjusted for longitude and for the difference between local time and the time kept. Where the full and change intervals are used, and where the intervals have not been adjusted, errors in the predictions may be greater than when adjusted mean intervals are used.

To Find the Time of High Water. Add the high water lunitidal interval to the time of the Moon's transit at Greenwich.

To Find the Time of Low Water. Add the low water lunitidal interval, if given, to the time of the Moon's transit at Greenwich.

If the low water interval is not given, add 6^h 12^m to, or subtract 6^h 12^m from the time of high water.

To Find the Height of High Water. Assuming spring tides to occur one to two days after new or full Moon, subtract 1/7th of the difference between the heights of mean high water springs and mean high water neaps for each day that the predictions are from springs.

To Find the Height of Low Water. Subtract the height of high water from twice the height of mean level.

Examples of the above predictions are given on pages 30 and 31 in Part III of the *Tide Tables*, but it must be borne in mind that these methods must be memorised because the non-harmonic constants should only be used when the *Tide Tables* are not available.

CO-TIDAL CHART OF THE BRITISH ISLES AND ADJACENT WATERS

This chart, which is included in the *Atlas of Tides and Tidal Streams*, shows co-tidal and co-range lines in the waters surrounding the British Islands, and provides a means of predicting tidal information in the open sea in these areas. High water occurs at the same time at all points on a co-tidal line, and the mean range of the tide is the same at all points on a co-range line.

The co-tidal and co-range lines refer to the principal lunar semi-diurnal constituent M_2. The chart should therefore be used only when it is required to predict tides at sea, and the predictions should be regarded as approximations.

Against each co-tidal line is given a time difference on a standard port and the mean high water interval, and against each co-range line, a ratio of ranges on a standard port and the mean range of the tide.

The differences and ratios should always be used for predicting if the *Tide Tables* are available. When the *Tide Tables* are not available, spring rise should be assumed to be mean range multiplied by 1·3 and neap rise to be equal to mean range. The prediction is then the same as the method of using non-harmonic constants. The predictions by both methods are in Greenwich time for the whole area of the chart, and this fact must be remembered if the ship's clocks are set to Central European time, Netherlands time, or B.S.T.

TO FIND THE HEIGHT OF THE TIDE AT ANY TIME WHEN PREDICTING BY METHODS OTHER THAN THE ADMIRALTY METHOD

Once the times and heights of high water and low water at a place are found by any method except the harmonic and Admiralty methods, the height of the tide at any intervening time can be

found by using Table I (Supplementary Tables) in Part I of the *Tide Tables* or in Table VII in Part III of the *Tide Tables*.

These tables, called θ tables, described in Part I of the *Tide Tables*, assume the tide to rise and fall harmonically, and make use of the *duration of rise*, which is the interval between the times of L.W. and the next following H.W. and the *duration of fall*, which is the interval between the times of H.W. and the next following L.W.

If the duration of rise or fall is more than 8 hours, the directions on page 19 of Part III of the *Tide Tables* must be followed.

ADMIRALTY TIDE TABLES

Admiralty Tide Tables are published in three parts.

Part I. This is published annually in two sections and gives the daily times and heights of high water and low water at standard ports. The sections are in separate volumes, the area included in each being approximately :

Section A—Home Station
Section B—Foreign Stations.

The predictions in Section A are not repeated in Section B with the exception of those for ports near the common limits of the sections.

At the back of the book there are various tables, with full explanations :

(*a*) for finding the height of the tide at times between high and low water.
(*b*) for converting feet to metres.
(*c*) giving details of local conditions at certain ports.
(*d*) giving the tide levels and datums at the ports.

Part II. This is published every five years and gives the following tidal and tidal stream information :

1. The harmonic constants of the four principal constituents of the tide and the height of mean sea-level above chart datum for all places when they are known.

2. The time difference and ratio of ranges on a standard port for places where the method is applicable. The difference and ratio are used only when predictions are required quickly and no great accuracy is necessary.

3. Tables of seasonal corrections to heights, shallow water corrections, etc., for places where these corrections are known and are appreciable.

4. The harmonic constants of the four principal constituents of the tidal stream for places where a large diurnal inequality or other cause makes the method of prediction by reference to the tide at a standard port unsuitable. In addition, tables of corrections for currents are given where these corrections are appreciable.

Predictions from the constituents are made on Forms A and B as described on pages 32 and 33 in Part III of the *Tide Tables*.

Part III. This contains the following information :

1. Explanations of all methods of predicting tides and tidal streams from data given in Admiralty publications.
2. Instructions for predicting by the above methods, with examples.
3. Explanations, instructions and examples of the method of analysing short periods of observations of tides and of tidal streams.
4. Tables to assist prediction and analysis.

SUMMARY OF EXAMPLES IN TIDE TABLES, PART III

EXAMPLE	*PAGE*
1. **By the Admiralty Method Using Forms A and B.**	
(*a*) To find the times and heights of H.W. and L.W Large diurnal tide with no shallow water corrections. Form A	26
(*b*) To find the times and heights of H.W. and L.W. Semi-diurnal tide with large shallow water corrections. Form A	28
(*c*) To find the height of the tide at a definite time. Form B	27
2. **By Differences and Ratios.** To find the times and heights of H.W. and L.W. ..	29
3. **By Non-harmonic Tidal Constants.** To find the times and heights of H.W. and L.W. ..	30
4. **By the Co-tidal Chart of the British Isles and Adjacent Waters.** To find the times and heights of H.W. and L.W. ..	30
5. To find the intermediate heights of the tide by θ Table. (Table 7)	39 to 41

TIDAL PHENOMENA

Equinoctial and Solstitial Tides. It has been explained how the height of the tide not only varies with the relative positions of the Moon and Sun, but also with their declinations. If at springs these causes all tend to increase the height of the high water, spring tides higher than the normal are experienced. This occurs at about the equinoxes, that is, during September and March, when the Sun and Moon have no declination, and the tides are known as *equinoctial tides*.

If at springs these causes all tend to lower the height of the semi-diurnal high water, spring tides lower than the normal are experienced. This occurs at about the solstices, that is, during June and December, and the tides are known as *solstitial tides*.

Single Day Tides. At certain places the form of the composite tide wave will be diurnal, and when this occurs there may be only one high water and one low water a day. These are known as *single day tides.*

Shallow Water Effects. At certain places the shallow water effects are so great that more than two high waters and two low waters in a day are caused. As many as four high and four low waters may be caused.

This phenomenon is manifest in many different ways. At Portsmouth there is no visible double high water, but there is a prolonged stand of the tide at high water. The second low water is, however, visible between $2\frac{1}{2}$ hours and 3 hours after the first low water. At Southampton there are two high waters of about equal height, with an interval of two hours between them. Further west, at Portland, the predominating feature is a double low water, locally known as the *Gulder.* Double tides also occur on the Dutch coast and at other places.

The rise and fall of these tides cannot be assumed to be harmonic. For this reason, special tables are provided in Part I of the *Tide Tables* for finding the height of the tide at several places inside the Isle of Wight at intervals from low water at Portsmouth and Southampton. An explanation of the use of these tables is given with them.

Bores. The natural shape of any wave is regular, but when a wave enters shallow water its front slope increases and its rear slope decreases in steepness. In rivers and estuaries, and in shallow water generally, the duration of rise is therefore less than the duration of fall. In rivers the steepness of the front slope may be greatly increased and the wave tends to break ; should it break a bore occurs in which half or more of the total rise of the tide may occupy only a few minutes. Notable bores occur in the Severn, Seine, Hoogly and Tsien-tang-kiang.

Meteorological Tides. Local meteorological phenomena such as periodic winds, seasonal changes in the atmospheric pressure and the alternations of wet and dry seasons, may cause periodic changes in sea-level. These changes are called *meteorological tides.*

Non-periodic Meteorological Phenomena. The tides are affected by the changes in the force and direction of the wind, and the height of the barometer. No absolute rule can be given, the effects being continental rather than local in effect ; for example, strong east winds over northern Europe are ' onshore ' winds on the east coast of England and ' off shore ' winds to Europe generally, the general effect being to lower the height of mean level in the North Sea.

TIDAL STREAMS

Tidal streams are generated by the same forces as produce tides, and for this reason the Admiralty method of predicting tides

can be used for predicting tidal streams. Details and instructions for this prediction are given in Part III of the *Tide Tables.*

Over the oceans the tidal wave is *progressive.* In a progressive wave, water runs in the direction of progress of the wave where the water-level is above mean level, that is, from half tide (rising) to half tide (falling). The water runs in the opposite direction from half tide (falling) to half tide (rising) and slack water occurs at half tide. Slack water is the interval between the cessation of the stream and its beginning to run in the opposite direction. This movement is shown in figure 130.

In an estuary or in a land-locked stretch of water not itself affected by tides except through a narrow entrance, the tidal stream tends to take the form of a *stationary* wave, a tendency that causes water to flow towards the place where the level is rising, away from the place where the level is falling, and slack water to occur at about high or low water. When the stream turns within an hour of high or low water by the shore, it may be referred to as

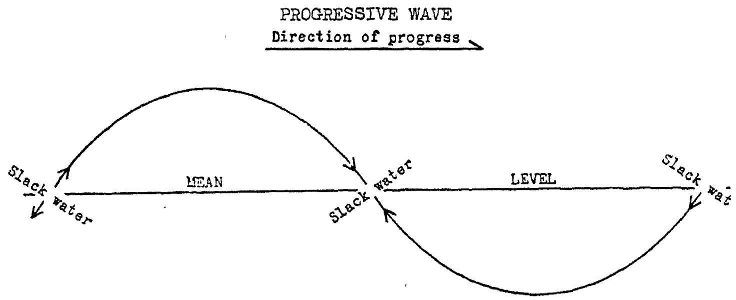


FIGURE 130.

the *flood* stream when the tide is rising and as the *ebb* stream when falling. If the stream turns at any other time, it must be referred to as *ingoing, outgoing, north-going, south-going,* etc.

The terms 'flood' and 'ebb stream' should be used with caution because they may lead to confusion. The other terms mentioned are therefore preferable.

From the above it is seen that when the tide is a stationary wave, the flood stream runs while the tide is rising and the ebb stream while it is falling, and that slack water occurs at about high or low water. This movement is shown in figure 131.

The tide inshore is never entirely progressive or entirely stationary, but slack water occurs offshore at about half tide, and in estuaries, etc., at about high and low water. For example, off the west coast of Ireland the tidal stream turns at about half tide, whereas in the English Channel it turns at about high and low water.

It is unwise to predict the time of slack water merely from the configuration of the land or the known time of high water because many circumstances influence the formation of tidal streams.

Tidal Streams in Channels. Suppose the tide wave moves along a coast, and passes a narrow entrance to a land-locked stretch of water not itself affected by tides except through this entrance. When the crest of the wave passes this entrance—that is, at high water—the level at the entrance will be higher than the level inside, and a stream will flow in. At half tide the levels at the entrance and inside will be about the same, and there will be no flow. At low water the level of the entrance will be below that inside and a stream will flow out. Thus slack water occurs at about half tide.

In well-defined channels the stream usually follows the direction of the channel. Outside the limits of the channel, it may be rotary, setting towards a different point of the compass at each hour of the tide. The direction will be the same at any given interval from high water, and the velocity will vary with changes in the tidal range, being usually greatest at springs and least at neaps.

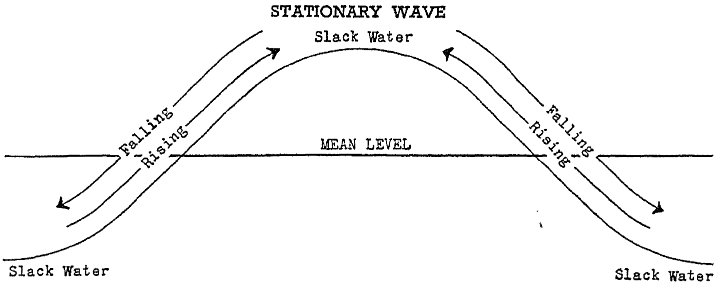


FIGURE 131.

If a channel connects two bodies of tidal water, the direction and rate of the stream will depend on the relative heights at each end. In the entrance to a river, the time of slack water may be considerably affected by the river current.

The Effect of Land. When a tidal stream meets an obstruction, either land or a shoal, its direction is changed either horizontally or vertically, and its velocity is altered. When the velocity is great and the change of direction upwards, as happens at Portland, a *race* may occur. This consists of heavy breaking seas, *overfalls* and *tide rips*.

When two streams running in different directions meet, eddies may be formed in which the stream has a circular motion. Details concerning eddies, duration of slack water, etc., are given in the appendix to H.D.291.

The Effect of Wind. Streams may be considerably affected in direction, duration, and velocity by the wind. No rule can be given for wind effects, but generally speaking, when the wind and stream are in the same direction, the duration and velocity will be increased, and when in opposing directions, the duration and

velocity will be decreased. This cannot be taken as an unvarying rule. For instance, a northerly wind in the North Sea increases the duration and rate of the south-going stream, and the water-level in the southern part is raised until a point is reached when the force of wind and head of water balance, the stream then becoming normal. If subsequently the northerly wind decreases in force, it will no longer suffice to support the head of water, and the duration and rate of the north-going stream will be increased, even though the northerly wind continues.

CURRENTS

Current, which may be either permanent, seasonal, or temporary, is caused mainly by wind. Much information is available about permanent and seasonal currents, and will be found in Chapter XV and in the *Sailing Directions*, current charts, etc., but these currents are uncertain, both in direction and rate, and may even run in a direction opposite to that expected. Temporary currents caused by the wind at the time, also uncertain, depend greatly on position, depth of water, etc., but they usually run approximately in the direction in which the wind is blowing and vary in rate with the force of the wind.

NOTE. Owing to a dynamical consequence of the rotation of the Earth, a drift produced by the wind on open water is usually directed to the right of the direction of the wind.

Information concerning permanent and seasonal currents at stations for which the harmonic stream constants are given is tabulated, if available, in Part II of the *Tide Tables* Current is not included in the tables of tidal streams, or in the directions and rates given on the tidal stream charts, except at stations where it always runs in approximately the same direction, as, for instance, in river estuaries. It is thus usually necessary to estimate the current from available information, such as the wind at the time, and the estimated current should be added to the tidal stream predicted. When current and stream are added, both must be resolved along the cardinal directions and combined accordingly—north to north, east to east, etc.

INFORMATION ABOUT TIDAL STREAMS

Full instructions for finding the direction and rate of the tidal stream in any part of the world are given in Part III of the *Tide Tables*. Information is also given on charts (see page 22), in the appropriate *Sailing Directions* and in the appendix to H.D.291.

Tidal streams are less easily observed than tides because there is not available, at present (1938), a meter that will give a reliable record of direction and rate without frequent attention for clock-winding and general supervision. What is required is an instrument comparable to the automatic tide gauge. Furthermore, streams

are necessarily observed from floating stations, and the observations obtained include, in addition to horizontal movements of the water, unknown horizontal movements of the station itself, which movements give rise to errors in the observations. For these and other reasons, streams are generally less accurately observed than are tides. Consequently the data for predicting is less accurate and the predicted stream less reliable.

In consequence of inaccurate data and unknown current, the predicted and actual horizontal movements of the water may differ considerably. All predictions of horizontal movement must therefore be considered as approximations.

Tidal Stream Arrows. The practice of using arrows to show tidal information was discontinued in 1933. On certain charts, however, arrows are still used when information suitable for the present tabular form is not available. These arrows are referred to on Chart 5011, a copy of which is to be found in the back of this Volume.

On all charts other than those where the arrow-method is used, tidal stream information is shown in the tabular form explained on page 22.

Atlas of Tides and Tidal Streams for the British Isles and Adjacent Waters. This atlas gives the details of the rate and direction of the tidal stream at one-hour intervals. A chart of co-tidal and co-range lines is included.

A full explanation is given on page 1 of the atlas.

CHAPTER XIII

ELEMENTARY METEOROLOGY

The subject of meteorology and weather forecasting is fully dealt with in the *Weather Manual*, and the object of the following chapters is to give a brief outline. Many of the diagrams in Chapters XIII and XIV have been taken by permission of the Meteorological Office from their various publications.

Introduction. The fact that Aristotle wrote the first treatise on meteorology shows that a great deal was known about the relations of wind and weather even then. The weather signs he described are similar to those heard to-day, and for a period of about 2,000 years no appreciable progress was made in formulating a theory that explained these signs.

Torricelli, an Italian, invented the barometer in 1643, and this led to the 'weather glass', with its inscriptions, 'stormy', 'much rain', 'rain', 'change', 'fair', 'set fair', and 'very dry'. Scientists at once realised the inaccuracy of these barometrical forecasts, but it was not until a hundred years later that an advance was made.

Then came a further interval of no progress which lasted until 1820, when the relation between wind and pressure distribution was first defined. Later, in 1857, the value of simultaneous observations of pressure, wind, temperature, and weather conditions at a number of places was fully appreciated, and the Dutchman, Buys-Ballot, produced his law, described later in this Chapter, which holds good to the present day.

In 1860 Admiral Fitzroy, who was head of the Meteorological Office in London, which had then been established only a few years, began collecting daily reports by telegraph from various stations that described the local weather at certain fixed times. As a result of these reports the first weather forecasts were issued to the press.

International co-operation was established in 1872, and with the advent of wireless telegraphy an ever-increasing exchange of meteorological information became available.

At an early date it was recognized a knowledge of the conditions in the upper air is of assistance in weather forecasting, but it was not until the war of 1914–1918 that aircraft were used for observing upper-air temperatures, and the pilot balloon became the standard method for observing the upper winds.

In the short interval since the adoption of the pilot balloon, a large amount of information has accumulated concerning the winds

of the upper air over the continents, but information of conditions over the ocean is still urgently required.

An increasing number of H.M. ships are being fitted with pilot-balloon outfits, and it is expected that the resulting observations will be of great value when they are sufficiently numerous to be embodied in the various *Meteorological Atlases*.

THE ATMOSPHERE

The air, which is referred to as the atmosphere, covers the whole surface of the Earth in the form of a thin film. Half of the total weight of this air is within about nine miles of the surface of the Earth ; above this is a further layer of nine miles containing about one quarter of the weight of the total mass, and the remaining quarter is spread up to a height of at least 130 miles.

At the height of the summit of Mount Everest, 29,000 feet, the density of the air is about two-fifths of the density at sea-level, and is so rarefied that great difficulty is found in breathing.

The air is a mixture of gases of which 99 % are oxygen and nitrogen. Also there is always present an appreciable quantity of water vapour. The amount of this water vapour, which is increased by evaporation and decreased by rain and dew, is always a variable quantity, and this fact accounts, to some extent, for the different weather experienced at a place.

Were it not for this water vapour in the atmosphere, the Earth would be subjected to extremes of temperature that would render life impossible.

PRESSURE

The film of air over the Earth exerts a pressure on the surface of the Earth in exactly the same way that the weight of sea water exerts a pressure on a diver.

Consider the column of air resting on one square inch of the Earth's surface. This column has a cross-section of one square inch and a height equal to that of the atmosphere. Its weight is $14\frac{1}{2}$ pounds, and this weight, which is called the atmospheric pressure, is measured by the barometer.

The Bar. Until recently it was the custom to measure barometric pressure in inches of mercury, but in modern meteorology the unit used is a *bar*, which is the pressure due to a column of mercury 29·53 inches high at the freezing-point of water in latitude 45°.

The bar is derived from the metric system in which a pressure of 1,000 dynes per square centimetre is equal to one millibar, a dyne being the force that, acting on a mass of one gramme, produces a velocity of one centimetre per second in one second.

The average atmospheric pressure at sea-level is 1,013 mb. or 29·91 inches. (1/10th inch of mercury = 3·4 mb.)

There are three types of barometer in general use :

1. the mercurial barometer.
2. the aneroid barometer.
3. the barograph.

THE MERCURIAL BAROMETER

The principle of the mercurial barometer is that a column of air in the atmosphere is balanced by a column of mercury.

In its simplest form it is merely a glass tube, closed at one end and filled with mercury. In order to extract any minute quantities of air which may be adhering to the sides of the glass, the mercury is boiled in the tube. The tube is then inverted and its open and placed below the level of the surface of the mercury in a small cistern. The mercury descends in the tube until the weight of the column is balanced by the pressure of the atmosphere on the mercury in the cistern, and the height of the mercury left in the tube affords a correct measure of the pressure. The exact pressure of the column is recorded by a scale of millibars, the zero of which is level with the surface of the mercury in the cistern.

THE KEW-PATTERN MARINE BAROMETER

H.M. ships are supplied with this type of mercurial barometer, which is fully described in the *Weather Manual* and shown in figure 132.

A vernier, operated by means of a milled head, enables readings to be made accurately to one-tenth of a millibar.

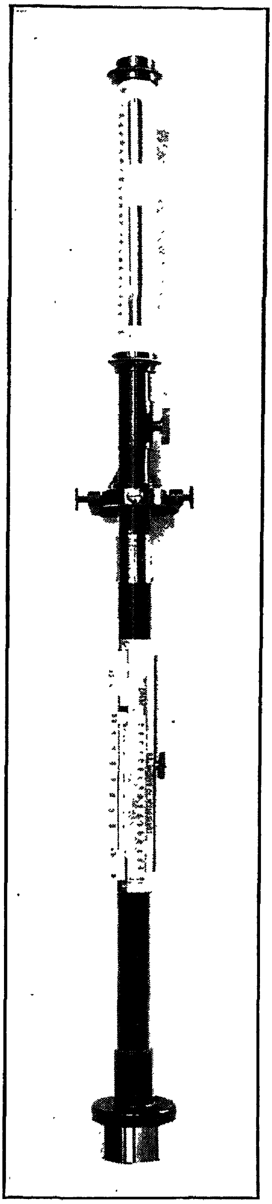
PROCEDURE FOR READING

Read the attached *Gold slide,* which will be described later, before reading the barometer, because heat from the body of the observer will affect the thermometer more quickly than the barometer.

Tap the barometer gently with the finger until tapping no longer affects the shape of the mercury surface in the tube. Turn the milled head at the side of the instrument until the lower edge of the vernier and the lower edge of the sliding piece at the back of the instrument, which moves with the vernier, are in line and appear just to touch the uppermost part of the domed surface of the mercury. If the eye is not in line with both the bottom of the vernier and the sliding piece at the back, parallax will result. The vernier is read in the same way as a sextant. The reading is clearly shown in figures 133a (985·0 mb.) and 133b (1,012·7 mb.).

Pumping. When the ship is moving violently, the mercury may be jerked up and down along the scale. This is known as pumping. When a barometer is pumping, the value of the barometric pressure can be taken to be the mean of the highest and lowest heights

[To face p. 316.



MERCURIAL BAROMETER
FITTED WITH THE GOLD SLIDE

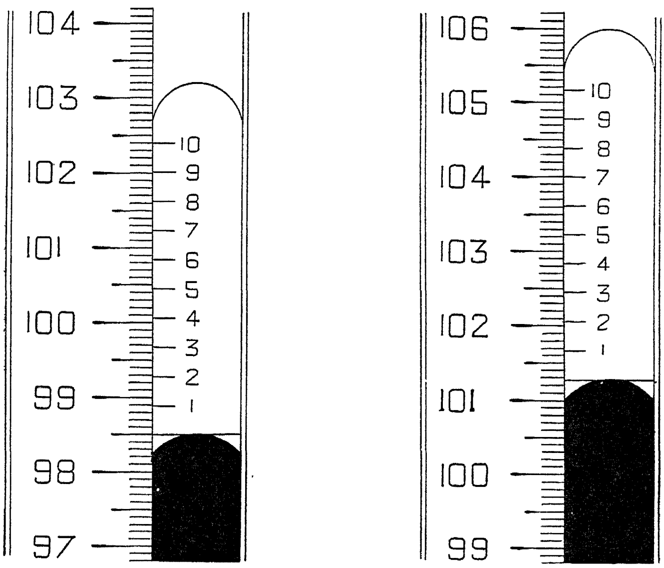
FIGURE 132.

reached by the top of the curved surface of the mercury during an interval of not less than one minute.

Corrections. Certain corrections have to be made to the actual readings in order to make the comparison of barometric observations possible. These corrections can be divided into two types :

1. Errors allowed for in the construction of the barometer which are described in the *Weather Manual.*
2. Corrections which have to be applied to each reading of the barometer. These are made by means of the Gold slide shown in figure 134.

READING THE SCALE



(a) (b)

FIGURE 133

Lieutenant-Colonel E. Gold, of the Meteorological Office, invented this slide, which automatically corrects the readings of a mercurial barometer for :

(*a*) index error
(*b*) latitude
(*c*) height
(*d*) temperature.

The instrument consists of a thermometer mounted alongside a scale marked ' Correction to Barometer ', the latter being movable by rack and pinion. At the top of the slide are two scales, one marked ' Latitude ', the other marked ' Height above Water Line '. The latitude scale is engraved upon a small strip of metal, the

position of which may be altered if two small screws at the back are loosened. The purpose of this movement is to provide means

THE GOLD SLIDE FOR
MERCURIAL BAROMETER

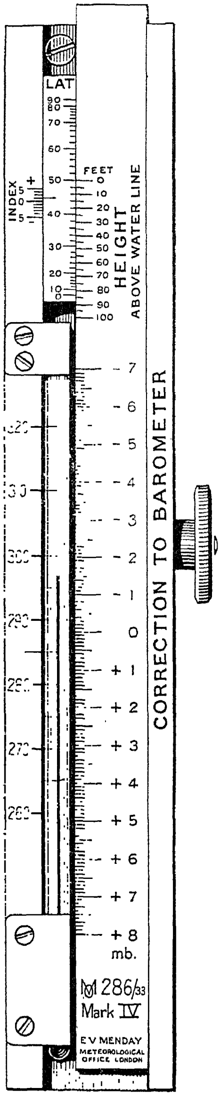


FIGURE 134.

of adjusting the scale, once and for all, to allow for the index error of the barometer upon which the slide is to be used.

When Gold slides are supplied with barometers, already fitted,

the necessary adjustments have been made in the Meteorological Office and no further alterations are necessary.

To Take an Observation. Knowing the latitude of the ship and the height of the barometer cistern above the water line, move the slider up or down by means of the rack and pinion until the latitude as shown on the latitude scale and the height as shown on the height scale come into coincidence. The correction to be applied to the barometer reading is then read opposite the top of the mercury column in the thermometer. If the correction is shown on the *red* part of the scale, that is, above the zero mark, it should be *subtracted* from the uncorrected barometer reading in order to reduce the reading to sea-level and latitude 45°. If the reading falls on the *black* part of the scale, that is, below the zero mark, it should be *added* to the uncorrected reading. Large divisions on the correction scale represent whole millibars ; the sub-divisions permit of reading to tenths.

When barometer readings are logged, the corrected reading should be inserted in the column headed *Corrected Barometer Pressure.*

If the ship does not change her latitude the Gold slide need not be touched.

Care of Gold Slides. The scales, which are silvered, should be kept serviceable by using a soft cloth or camel-hair brush to remove any dust or dirt. Metal polish should never be applied. A little clock-oil may occasionally be needed to keep the slider working freely, but only a mere trace should be used.

If the rack and pinion movement becomes stiff, it must be carefully dismantled. This can be done by first removing the entire slide from the barometer and placing it face downwards. A small brass block securing the pinion in position will then be seen. Remove this by taking out the four screws. Wipe the pinion and its bearing with a soft rag to remove dirt and old oil ; add a trace of fresh clock-oil and set it aside. Now remove the four small screws, two at each end of the rack. The slider can then be taken out. Wipe off all dirt and old oil from the rack and bearing surfaces. Put a drop of fresh clock-oil on the rack and on the back of the slider. Reassemble, taking care to see that the pinion is properly engaged in the rack before tightening the screws. The slider should then move up and down quite smoothly. Needless to say, the screws which secure the latitude scale should not be touched during the above operations.

Care and Maintenance of a Kew Barometer. A small metal arm with gimbals is supplied with the barometer for its suspension, and a place should be chosen for it, low down, out of the way of traffic, and in as uniform a temperature as possible.

Having set up the bracket, carefully remove the barometer from its box ; bring it gradually to an upright position, and then ship it in the gimbals.

If the mercury does not immediately leave the top of the tube, the cistern should be gently tapped with the fingers.

Allow an interval of a few hours before taking a reading because the instrument will need some time to take up the temperature of its surroundings.

Unshipping and Stowing. Take great care when handling the instrument because a sudden lowering of the top of the instrument generally causes a breakage, since the vacuum at the top of the mercury allows the mercury to move practically as if it were a solid metal rod. Barometers should be inverted very slowly and packed with their cistern end up. The handle of the barometer box is so fitted that when it is carried, the cistern end is slightly up.

THE ANEROID BAROMETER

This instrument consists of a thin cylindrical metallic chamber, partly exhausted of air and hermetically sealed. It is thus susceptible to the slightest changes in external pressure. The top of the chamber is connected to a pointer by an arrangement of levers and springs, and this has the effect of greatly magnifying its movements. This pointer can be set at any pressure by means of a screw at the back of the instrument. Since the metal of which the aneroid chamber is made cannot be relied on to maintain its form indefinitely, the zero varies slightly. The reading of the instrument should therefore be compared frequently with that of the mercurial barometer, as described later. Before the instrument is read, the glass face should be tapped gently.

The advantages of the aneroid are :

1. It is simple to read.
2. It is easily transported and may be placed or hung in any convenient position.
3. By adjusting the fixed or shorter pointer by means of the metal thumb screw at the centre of the glass face, it is readily apparent whether the barometer is rising or falling.

H.M. ships are supplied with either pattern 501, which is graduated in millibars and inches, or pattern 502, which is graduated in millibars only. The latter type, shown in figure 135, is gradually being brought into general use.

To Check an Aneroid Barometer with a Mercurial Barometer. Take the aneroid barometer to the mercurial barometer. Read the mercurial barometer in the usual way and make the proper Gold-slide correction, thus obtaining the corrected barometric pressure at sea-level. Set the aneroid to this reading by means of the adjusting screw at the back of the instrument. The aneroid will now register the corrected pressure at sea-level for the height at which it was corrected.

[To face p. 320.

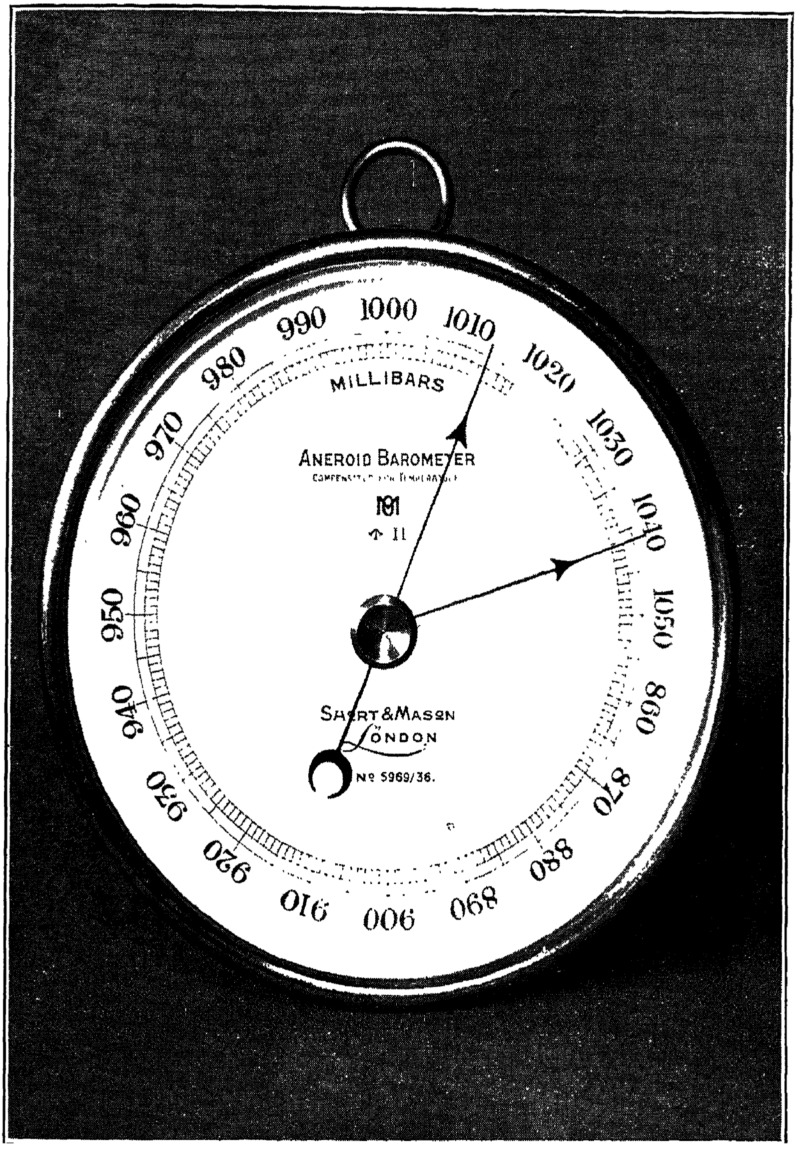


FIGURE 135.

To face p. 321.]

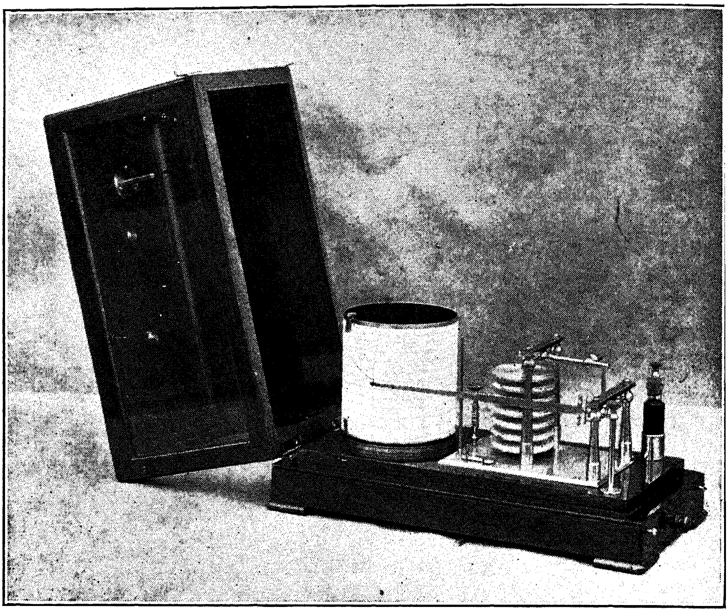


FIGURE 136.

An alternative method, which may be found convenient, is to ask a nearby ship, known to be fitted with a mercurial barometer, what the corrected reading for sea-level is, and to adjust the aneroid to that reading for the height of the actual position in which it is kept.

If the aneroid is moved to a higher position, as, for instance, the chart house, the reading must be increased by the adjusting screw by 0·34 mb. for every 10 feet that it is raised. If it is moved to a lower position, the reading must be decreased in a similar way.

To Log Aneroid Barometer Readings. Barometric observations in all H.M. ships which are supplied only with an aneroid barometer should be made and recorded in millibars. In the deck log, the actual pressure at sea-level should be recorded and, therefore, the reading must be corrected for the height of the barometer above sea-level, as described in the last paragraph, before being logged.

If the aneroid is kept in the chart house, this height correction should be made by the adjusting screw so that the aneroid will always record the pressure at sea-level.

THE BAROGRAPH

This instrument, as shown in figure 136, is an aneroid barometer provided with a lever which records variations of pressure on a revolving drum.

It is useful not only because it enables an observer to detect casual errors in the readings of the marine barometer, but also because it gives a continuous record of barometric pressure for reference. Barographs, moreover, register minor fluctuations of atmospheric pressure which are seldom noticeable in the action of the mercurial barometer. The instrument should therefore be secured or suspended in a position where it is least likely to be affected by concussion, vibration, or the movements of the ship.

The drum is driven by clockwork and makes one revolution in seven days. The paper forms, which fit on the drum, are graduated so as to show the day and time of day, as well as the height of the barometer in millibars and inches. Means are provided for adjusting the pen point so that it corresponds with the reading of the marine barometer, and a lever enables the pen to be withdrawn from the paper while the instrument is being moved or guns are being fired. If possible the barograph should be secured in an athwartship position so that the pen is least likely to leave the paper when the ship is rolling.

THE DIURNAL RANGE OF THE BAROMETER

This results from atmospheric pressure waves, with a period of nearly 12 hours, which sweep regularly round the Earth from east to west. They are at a maximum in the tropics where they are clearly indicated by the rise and fall of the barometer, as shown in figure 137. The barometer rises from 0400 to 1000, then falls

BAROGRAPH TRACE

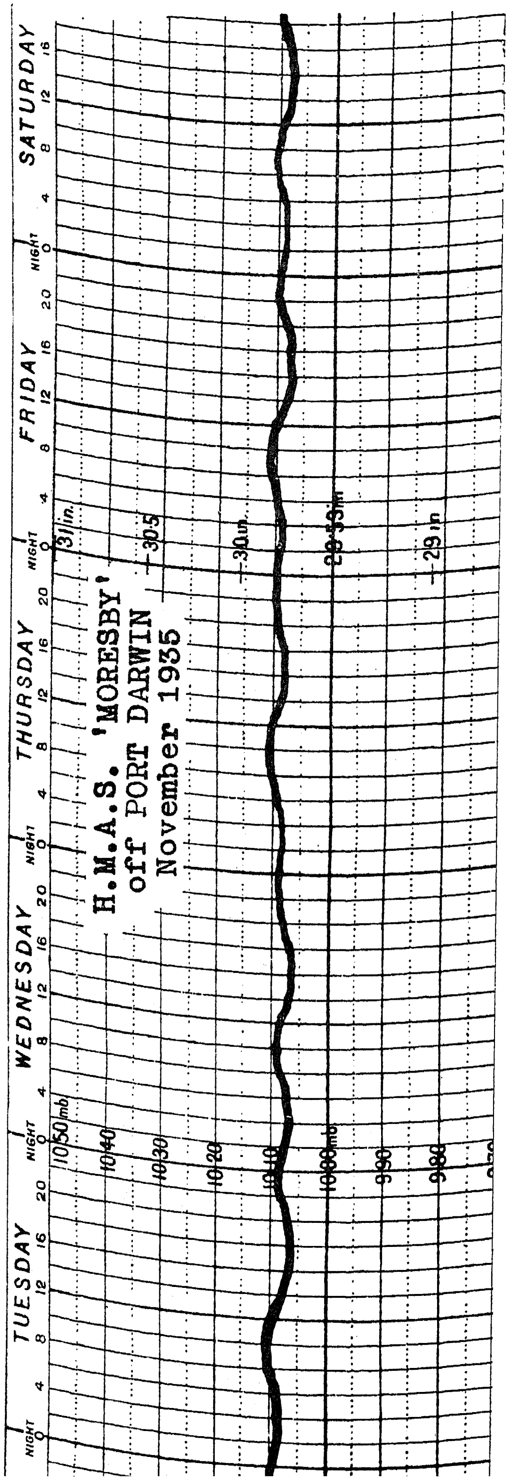


Figure 137.

Illustrating Diurnal Range of Atmospheric Pressure in the Tropics

until about 1600. After that it rises again till about 2200, when it once more falls until about 0400.

The diurnal variation has a range in the tropics of about 3 mb. In latitude 51° the range is about 0·8 mb, and in high latitudes is inappreciable.

GENERAL PRESSURE DISTRIBUTION OVER THE EARTH'S SURFACE

In order to illustrate the pressure distribution over the Earth's surface at any given time, simultaneous corrected barometer readings can be plotted. Lines called *isobars* are then drawn connecting places of equal pressure.

Between the latitudes of 20° and 40° there is usually a relatively high pressure over the oceans. These high pressure belts move slightly north and south as the Sun changes its declination.

On each side of these belts the mean pressure is relatively low although on the polar side it undergoes constant fluctuations due to atmospheric disturbances which will be considered later.

TEMPERATURE

The interchange of heat, between one body and another, occurs in one or more of three different ways :

Conduction is the transference of heat from one particle of a body to the next particle. Different substances vary in their degree of conductivity. Solids are usually better conductors than liquids, which in turn are better than gases.

Convection is the interchange of heat by means of warm currents of gas or liquid. The gas or liquid when heated expands, decreases in density, and rises. Colder gas or liquid flows in to take its place, and currents are created.

Radiation is the transmission of heat in the form of wave energy like that which enables the Earth to receive heat from the Sun.

Measurement of Temperature. Temperature can be measured according to various scales, those most frequently used being Fahrenheit, Centigrade and Absolute.

Some idea of the relative values of the scales can be obtained from the following table.

	Water freezes	*Water boils*
Fahrenheit	32°	212°
Centigrade	0°	100°
Absolute	273°	373°

Absolute temperature thus equals Centigrade temperature increased by 273°.

Table for Conversion of Degrees Fahrenheit into Degrees Centigrade and Degrees Absolute.

°F.	°C.	°a.	°F.	°C.	°a.	°F.	°C.	°a.	°F.	°C.	°a.
20	−6·7	266·3	45	7·2	280·2	70	21·1	294·1	95	35·0	308·0
21	−6·1	266·9	46	7·8	280·8	71	21·7	294·7	96	35·6	308·6
22	−5·6	267·4	47	8·3	281·3	72	22·2	295·2	97	36·1	309·1
23	−5·0	268·0	48	8·9	281·9	73	22·8	295·8	98	36·7	309·7
24	−4·4	268·6	49	9·4	282·4	74	23·3	296·3	99	37·2	310·2
25	−3·9	269·1	50	10·0	283·0	75	23·9	296·9	100	37·8	310·8
26	−3·3	269·7	51	10·6	283·6	76	24·4	297·4	101	38·3	311·3
27	−2·8	270·2	52	11·1	284·1	77	25·0	298·0	102	38·9	311·9
28	−2·2	270·8	53	11·7	284·7	78	25·6	298·6	103	39·4	312·4
29	−1·7	271·3	54	12·2	285·2	79	26·1	299·1	104	40·0	313·0
30	−1·1	271·9	55	12·8	285·8	80	26·7	299·7	105	40·6	313·6
31	−0·6	272·4	56	13·3	286·3	81	27·2	300·2	106	41·1	314·1
32	0·0	273·0	57	13·9	286·9	82	27·8	300·8	107	41·7	314·7
33	+0·6	273·6	58	14·4	287·4	83	28·3	301·3	108	42·2	315·2
34	1·1	274·1	59	15·0	288·0	84	28·9	301·9	109	42·8	315·8
35	1·7	274·7	60	15·6	288·6	85	29·4	302·4	110	43·3	316·3
36	2·2	275·2	61	16·1	289·1	86	30·0	303·0	111	43·9	316·9
37	2·8	275·8	62	16·7	289·7	87	30·6	303·6	112	44·4	317·4
38	3·3	276·3	63	17·2	290·2	88	31·1	304·1	113	45·0	318·0
39	3·9	276·9	64	17·8	290·8	89	31·7	304·7	114	45·6	318·6
40	4·4	277·4	65	18·3	291·3	90	32·2	305·2	115	46·1	319·1
41	5·0	278·0	66	18·9	291·9	91	32·8	305·8	116	46·7	319·7
42	5·6	278·6	67	19·4	292·4	92	33·3	306·3	117	47·2	320·2
43	6·1	279·1	68	20·0	293·0	93	33·9	306·9	118	47·8	320·8
44	6·7	279·7	69	20·6	293·6	94	34·4	307·4	119	48·3	321·3

THERMOMETERS

Temperature is measured by a thermometer.

In addition to the mercurial barometer, H.M. ships are supplied with ordinary thermometers, graduated from —15° to +115° Fahrenheit. Two are used in the psychrometer, which will be described later, and one is used for taking the temperature of the sea for entry in the ship's log.

THE TEMPERATURE OF THE ATMOSPHERE

The atmosphere derives its heat indirectly from the Sun. Its temperature depends not so much upon the direct rays of the Sun as upon the conduction and radiation from the surface of the Earth heated by the Sun's rays.

The Sun's rays have their greatest effect when they are perpendicular to the Earth's surface, and this effect diminishes as their obliquity increases. Also the land absorbs heat and loses it a great deal more readily than water. These two circumstances will be considered separately.

Over the Land. The surface of the Earth, to a depth of a few inches, is heated daily while the Sun shines, but the surface does not become hotter day by day because the accumulated heat is radiated back into the atmosphere and also transferred by conduction and convection. By conduction some of the heat which the surface receives during the day is transferred to the layer of the atmosphere in contact with the surface, but the effect of this transference is confined to a very shallow layer unless there is convection also, and, in general, the effect is small compared with that of radiation.

The effect of radiation is most marked at night when the sky is clear, since it causes the surface to become increasingly colder through the night. Clouds reduce the fall in temperature that results from the loss of heat by radiation at night, because they intercept and largely radiate back this heat. By day they check the rise in temperature by reflecting away much of the Sun's heat.

The temperature of the atmosphere over the land normally rises rapidly at the surface and at a progressively smaller rate up to a height of about 1,500 feet, from sunrise until about 1400 L.M.T.

Over the Sea. Unless the Sun is almost directly overhead, the greater part of the heat from the Sun's rays is reflected back to the sky and very little heating of the water occurs. When the Sun is overhead, the amount reflected by the sea is small, but the rays penetrate to a considerable depth so that the increase in the surface temperature is very slight and there is practically no change in the temperature of the air at the surface.

The temperature of the air over the sea changes mainly as a result of changes in the place of origin of the wind. The influence of clouds upon the air temperature over the open sea is negligible.

The Effect of Local Heating. The surface of the Earth consists of different formations in different localities, and the heating effect of the Sun's rays varies accordingly. For instance, a tarmac road is heated to a much greater extent than a plantation of trees growing nearby. The air becomes heated to a different extent in the neighbouring localities.

Warm air is lighter than cold air and therefore rises, if surrounded by colder air, in the same way that bubbles of air rise from a diver below the sea.

Atmospheric pressure decreases with height on account of the smaller column of air overhead, and this causes the warm air to expand, thus losing heat and becoming colder.

Stable and Unstable Conditions. Under certain conditions the temperature of the upper air falls off unduly fast, with the result that any air which is heated by contact with the surface of the Earth will, as it rises, always find itself in relatively cooler surroundings and will thus continue to rise to a considerable height.

This action sets up convection currents, and in these circumstances the atmosphere is said to be *unstable.*

On account of the convection currents usually prevalent when the atmosphere is unstable, violent phenomena, such as thunderstorms, squalls, heavy showers of rain or hail, may be experienced.

If, on the other hand, the temperature of the upper air is falling off with undue slowness, the rising mass of air will soon reach a level where the temperature of the surrounding air is equal to its own temperature, and it will therefore cease to rise. The atmosphere is then said to be *stable.*

In certain circumstances the temperature of the air actually increases with height. When this occurs, there is said to be an *inversion* of temperature. An inversion thus invariably indicates that the atmosphere is stable.

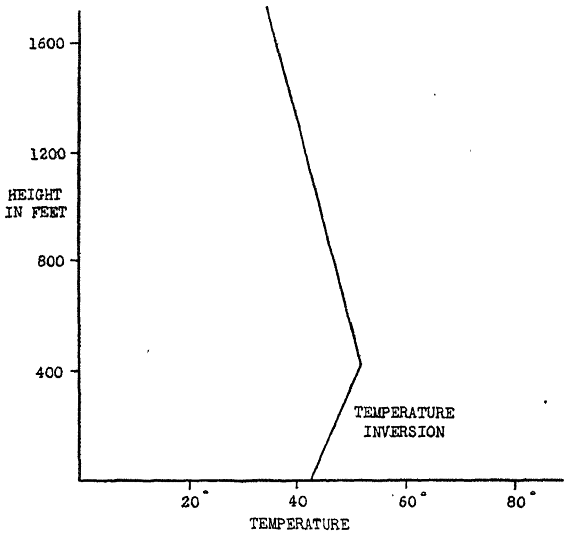


FIGURE 138.

Inversions are common near the ground and are then called *ground inversions.*

During the night when the sky is clear, radiation continues for a long period with a consequent cooling of the surface of the Earth. The layer of air in contact with the Earth is then reduced to a temperature considerably below that prevailing in the atmosphere 200 or 300 feet above it, as shown in figure 138.

Inversions may occur at any height. If so, the temperature first falls in the normal way ; then rises through the inversion, and afterwards begins to fall again. An example is shown in figure 139.

The Troposphere and Stratosphere. The atmosphere can be regarded as being divided into two separate parts so far as temperature is concerned, as shown in figure 140.

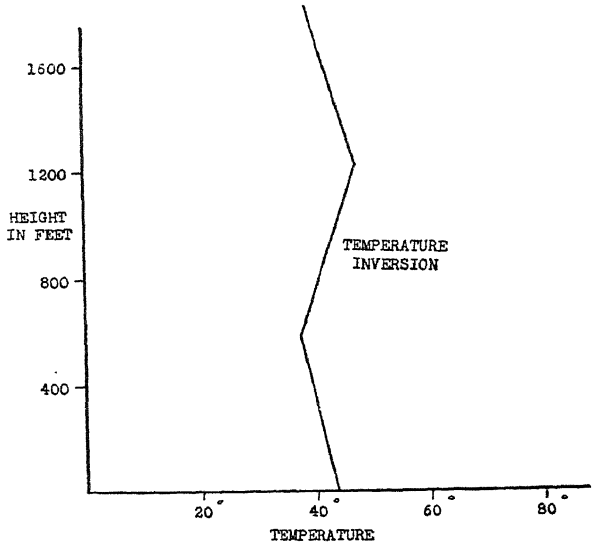


FIGURE 139.

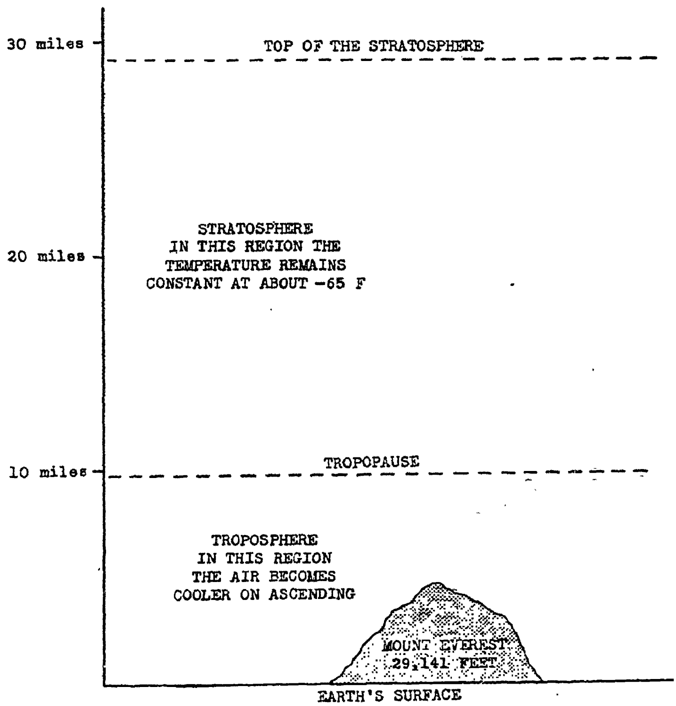


FIGURE 140.

1. The lower part extends to a height of about ten miles above the equator and five miles above the poles, and in it there is a fairly regular and considerable lapse of temperature with height. This region is known as the *troposphere.*

2. The upper part extends for about twenty miles above the troposphere. In it there is no material change of temperature with height. This region is called the *stratosphere.*

The level of change between the troposphere and the stratosphere is known as the *tropopause.*

WIND

If all parts of the Earth's surface had the same temperature, the surface pressure would everywhere be the same, and there would be no wind. The primary cause of all wind is a difference of temperature which in turn is sometimes responsible for differences of barometric pressure. Warm air rises and cooler air flows to take its place. Also air tends to flow from an area of relatively high pressure to an area of lower pressure. This flow of air is known as *wind.*

The Effect of the Earth's Rotation on the Wind Direction. On account of the Earth's rotation a mass of air which is drawn towards a centre of *low pressure,* is deflected to the *right* in the *northern hemisphere,* and a circulation is set up in an *anticlockwise* direction about the centre. Around a centre of *high pressure* a *clockwise* circulation is set up in the *northern hemisphere.*

In the *southern hemisphere* these directions are reversed.

Buys-Ballot's Law. These rotating movements explain the law which takes its name from a Dutch professor.

Stand with your face to the direction to the true wind, and the centre of low pressure will be about 8–12 *points on your right hand in the northern hemisphere, and on your left hand in the southern hemisphere.*

The practical value of this law to the seaman is described in the section dealing with tropical revolving storms.

Backing and Veering. When the wind changes in a clockwise direction, that is N.–E.–S.–W., it is said to *veer*; when it changes in the reverse direction it is said to *back.* These terms are used both in the northern and southern hemisphere.

Surface Wind. It is necessary to consider the effect of friction on wind passing over the Earth's surface. At heights of about 1,500 feet above the sea, surface friction is almost negligible and the wind blows along the isobars. Near the Earth's surface, however, the observed wind-speed is considerably reduced, more so over the land than over the sea.

This reduction in speed of the surface wind causes the wind to leave the isobars and flow either towards a centre of low pressure or away from a centre of high pressure.

Cyclonic Winds. A wind circulation about an area of low pressure is said to be *cyclonic*.

In figure 141, the isobars are circular and evenly distributed about the centres of high and low pressure. Actually they are

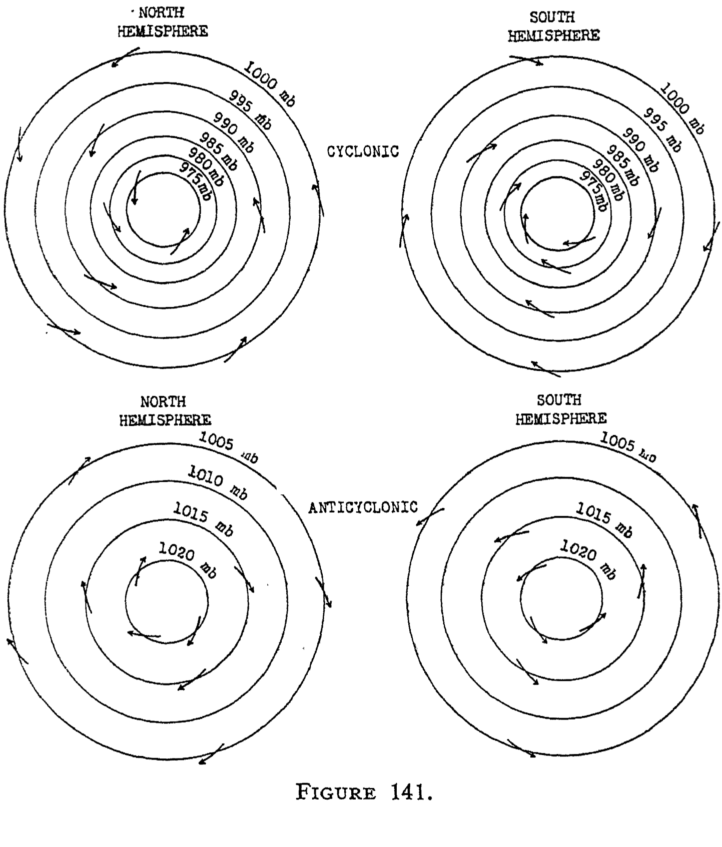


FIGURE 141.

seldom found in this form. In *cyclonic depressions* the shape of the isobars is usually oval.

In a cyclonic circulation the inward inclination of the wind direction to that of the isobars, is about 20° to 30° in the latitude of the British Isles. In the tropics the angle of inward inclination is greater. The outward inclination for an anticyclonic system is similar.

Anticyclonic Winds. A wind circulation about an area of high pressure is *anticyclonic*, as shown in figure 141.

PERMANENT WINDS

All the winds and regions so far mentioned are shown in figures 142, 143 and 144.

In addition to irregular disturbances there are a number of permanent winds, the cause of which is evident from the *Mean Barometric Pressure Charts* for January and July shown in figures 145 and 146.

From these charts it is seen that in both summer and winter there is a belt of nearly uniform pressure distribution round the equator. This belt is known as the *Doldrums,* and is a region of calms or very light variable winds, intermittent heavy rain and

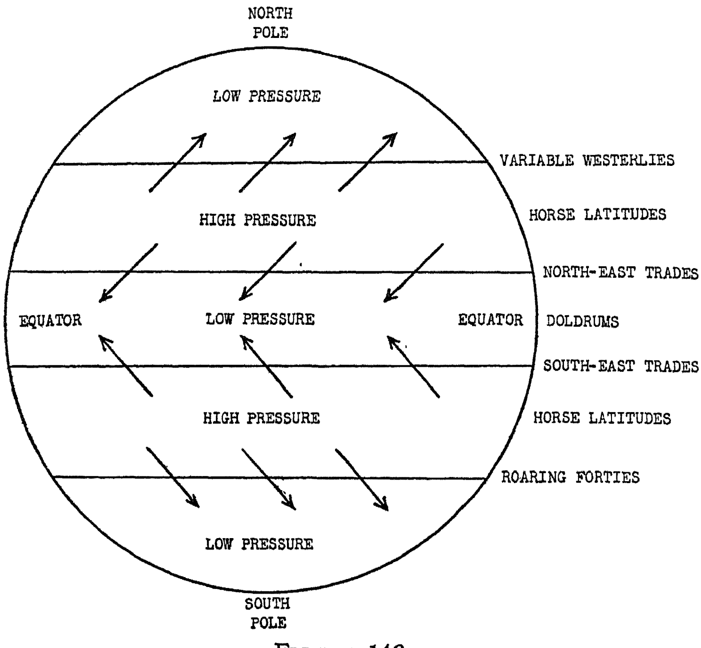
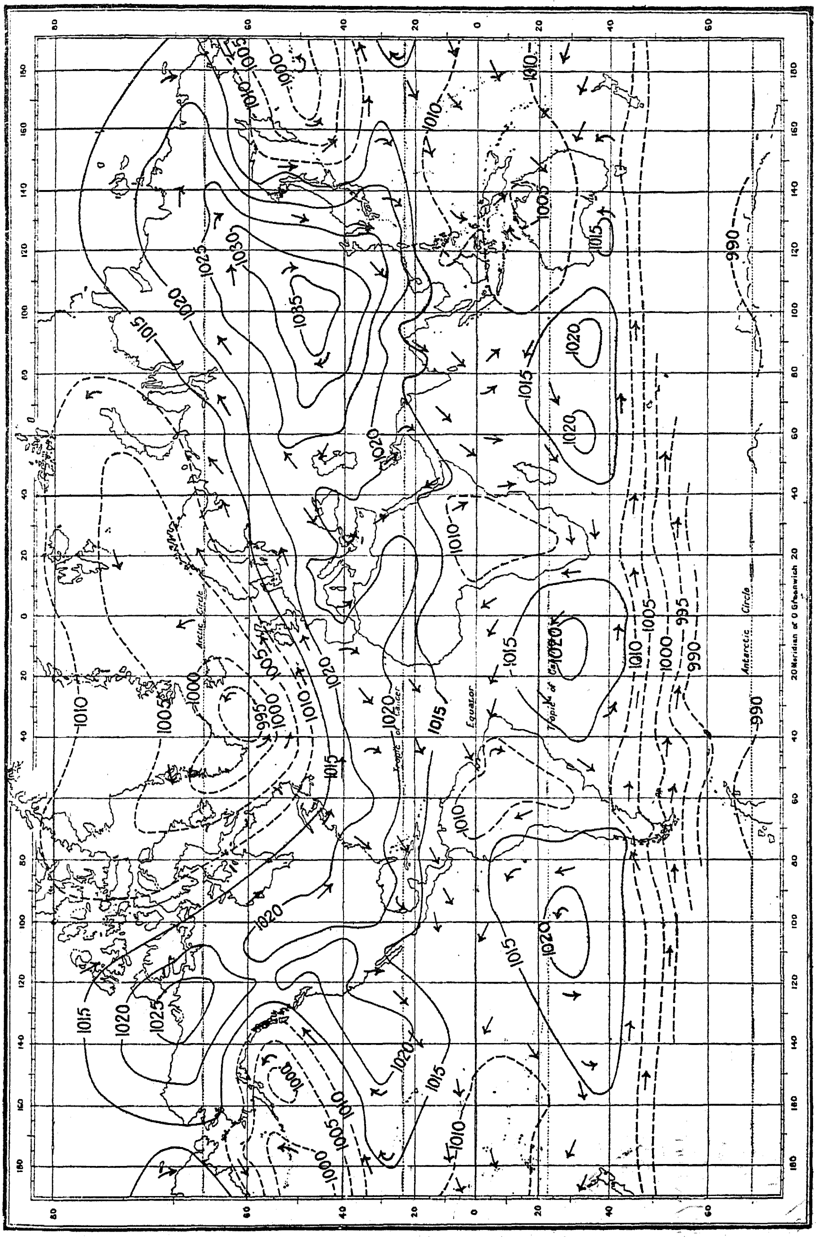


FIGURE 142.

thunderstorms. To the north and south of the Doldrums there are belts of high pressure having easterly winds on their equatorial sides and westerly on their polar sides. In the centre of each belt there is a region of calms and light winds. These three circumstances will be considered separately.

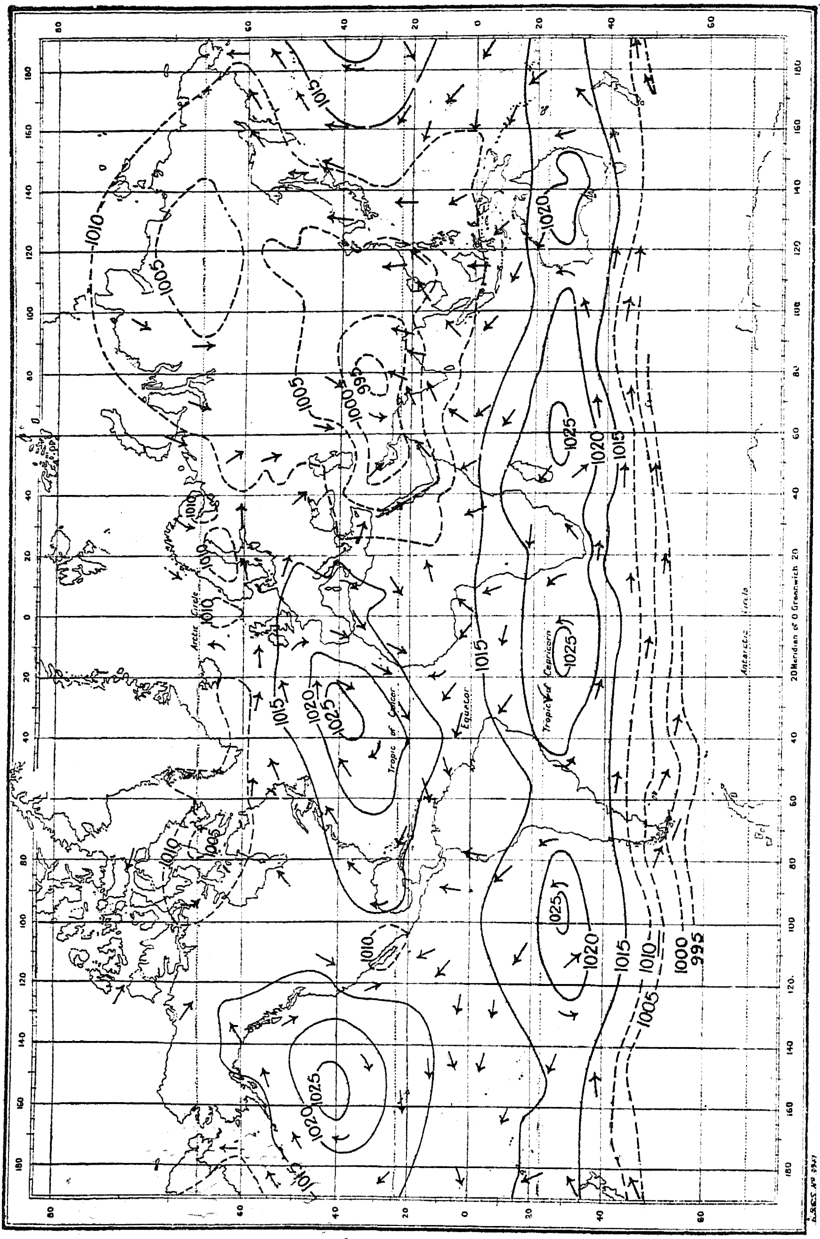
The Trade Winds. The winds on the equatorial sides of the high-pressure belts blow in towards the Doldrums from the *north-east* in the *northern hemisphere* and from the *south-east* in the *southern hemisphere,* and are called the *Trade Winds.*

The regions of calms and light winds in the centres of the belts are called the *Horse Latitudes.*



Average pressure at mean sea-level and prevailing winds at the surface in January.

FIGURE 145.



Average pressure at mean sea-level and prevailing winds at the surface in July.

FIGURE 146.

The following are the average limits of the Trade Winds in the different seasons.

N.E. TRADE WIND OF THE ATLANTIC OCEAN	January	2°N. to 25°N.
	July	10°N. to 30°N.
S.E. TRADE WIND OF THE ATLANTIC OCEAN	January	Equator to 30°S.
	July	5°N. to 25°S.
N.E. TRADE WIND OF THE PACIFIC OCEAN	January	4°N. to 25°N.
	July	12°N. to 30°N.
S.E. TRADE WIND OF THE PACIFIC OCEAN	January	4°N. to 30°S.
	July	8°N. to 25°S.
S.E. TRADE WIND OF THE INDIAN OCEAN	January	15°S. to 30°S.
	July	Equator to 25°S.

The Counter Trade Winds blow above and in the reverse direction to the Trade Winds and so maintain a circulation of air between the tropical and sub-tropical regions. This is demonstrated by the fact that there are constant S.W. winds at the peak of Teneriffe, while at sea-level there is an equally constant N.E. Trade Wind blowing. Again, on one occasion the ashes from an eruption in Central America were deposited four days later in Jamaica in the teeth of the N.E. Trade Wind.

The Westerlies. The westerly winds, called *Westerlies,* are much more variable in the northern hemisphere than are the Trade Winds because the low pressure belt in northern temporate latitudes is not permanent but consists of a frequent succession of detached low pressure formations, called *Depressions.* (See Chapter XIV.)

The Roaring Forties. In the southern hemisphere the unobstructed belt of ocean in latitude 60°S. allows the westerlies to acquire large speeds and blow for days. In latitude 40°S. these westerly winds alternate between S.W. and N.W. and are called the *Roaring Forties.*

Further information obtainable from these charts will be described later in this Chapter.

PERIODIC WINDS

Periodic winds depend on the mean barometric pressure ; the presence of land and the diurnal variation.

The Mean Barometric Pressure Charts show that the pressure over the sea is much more uniform throughout the year than over the continents. It is seen, for example, that pressure over Asia is low in summer and high in winter.

These charts and similar meteorological charts are very useful to the seaman in tropical waters because they enable him to compare the barometer readings he obtains with the general mean. Any great difference from the mean will be a warning of one of those non-periodical variations of pressure which indicate the presence of a tropical revolving storm.

The Effect of Land. Land is much more susceptible to the Sun's rays than water, and this has a considerable effect in modifying the general distribution of pressure. The alternate heating and cooling of the air in contact with it, gives rise to periodic winds of similar type but of different periods. Those with short periods are *land and sea breezes* and winds that are called *katabatic* and *anabatic*.

Those with periods lasting several months include the *Monsoons*.

The Diurnal Variation of Wind. Land and sea breezes are felt in fine weather on nearly all coasts and particularly at the larger islands in the tropics, as for instance in the West Indies. The land becomes heated during the day, and a breeze draws in from seaward which continues until towards evening. During the night the land radiates its heat more rapidly than the water and a land breeze springs up and blows throughout the night.

Monsoons of the Indian Ocean and China Sea. It has been seen that under normal conditions there are permanent areas of high pressure in latitudes 30°N. and 30°S. If, however, there is a large tract of land in this belt of latitude, that part of the belt will, in summer, become even more heated than the ocean in the vicinity of the equator, and thus cause a relatively low pressure to form over the land. This actually happens over the vast continent of Asia. In summer the land is heated; a low pressure is formed over the continent, and consequently the N.E. Trade does not blow in that season, but gives way to a south-west wind.

In winter the reverse happens; the land radiates its heat rapidly; a very high pressure is formed over Asia, and the N.E. Trade blows normally. These periodic winds are experienced in the Indian Ocean and China Sea, and are known as Monsoons. (See figure 143, wind chart for January, February and March, and figure 144, wind chart for July, August and September.)

In the northern summer, the centre of low pressure is approximately over N.W. India, and the barometric gradient becomes steeper as the centre is approached. Consequently the *S.W. Monsoon* in the Indian Ocean is a strong wind, reaching gale force at times whereas in the China Sea it is a light or moderate wind.

In the northern winter, the centre of high pressure is situated over eastern Asia, and consequently the *N.E. Monsoon* is a strong wind in parts of the China Sea, whereas in the Indian Ocean it is light to moderate.

The Monsoons extend from the middle of the Mozambique Channel along the east coast of Africa to a point north of the equator. From there they reach over the Gulf of Aden, Arabian Sea, Bay of Bengal and the China Sea as far as the meridian of 140°E., and the S.W. Monsoon continues until it meets the Trade Wind of the North Pacific Ocean.

The N.E. Monsoon seldom reaches as far south as the Mozambique Channel, except occasionally in January.

From November to March the N.E. Monsoon blows across the equator, and changes its direction in accordance with the law governing the relation between direction of wind and pressure for the southern hemisphere. It forms the *N.W. Monsoon*, which blows from directions varying from north-west to south-west, between 4°N. and 13°S., and from longitude 50°E., past the north of Australia. Sometimes it is felt as far east as the New Hebrides in the Pacific Ocean.

The following are the approximate seasons of the Monsoons :

S.W. Monsoon—May to September
N.E. Monsoon—October to March.
N.W. Monsoon—November to March.

Winds in the Red Sea. The prevailing wind is north-north-west from June to September throughout the whole length of the sea, but, owing to the N.E. Monsoon in the Indian Ocean, from October to April a south-south-east wind prevails in the southern part and a north-north-west wind in the northern part. Between them there is a belt of comparatively low pressure, calms and light airs. This belt varies in size and position during the winter.

Winds Round Australia. Another typical example of the effect of land is seen in the winds that circulate round Australia.

In the southern summer, a low pressure is formed over the land; the circulation is cyclonic, and, following the usual law of the southern hemisphere, the wind blows clockwise round the area of low pressure.

In the southern winter, a high pressure is formed over the land, the circulation is anticyclonic, and the wind blows anticlockwise. Tropical revolving storms occur mainly from December to April off the north-west coast (Willy-willies) and the north-east coast (Queensland hurricanes).

Winds on the East Coast of South America. South of about 15°S., the S.E. Trade Wind does not reach the coast. During the southern summer, an area of low pressure is formed over the centre of Brazil. This causes a N.E. Monsoon to blow along the coast as far south as the Rio de la Plata. During the winter south-west and south-east winds prevail. *Line squalls* (which will be explained later) cause violent south-westerly gales, called *Pamperos*, and are experienced in the vicinity of the Rio de la Plata from July to September.

Winds in the Vicinity of Cape Horn. The prevailing wind is westerly. Gales from directions between south and north-west occur at all seasons. Easterly gales sometimes occur in winter. The summer is usually wetter than the winter.

Winds in the Vicinity of the Cape of Good Hope. The prevailing winds are south-easterly in the summer and westerly in the winter. Gales from between north-west and south-west are most frequent in June and July, but they may occur at any time of the year.

West African Monsoon. The S.E. Trade Wind of the Atlantic Ocean does not extend into the Gulf of Guinea. Inside a line joining Sierra Leone and Walvis Bay, a permanent south to south-west wind prevails, because the pressure over Africa is lower than that over the ocean. It is known as the *West African Monsoon.* Between June and September, because the low pressure over Africa extends to the north-west, the northern position of this wind extends over the Atlantic, between the equatorial limits of the N.E. and S.E. Trades, as far as about 32°W.

Winds on the West Coast of Africa. As previously stated, the south and south-west wind of the West African Monsoon prevails. From Cape Bojador to Bathurst the N.E. Trade Wind blows throughout the year. Southward of this the winds are mainly from between south and west, although the Harmattan, from between north-east and east, blows from December to February.

MEDITERRANEAN

Winds in the Straits of Gibraltar. The winds are mainly westerly and easterly. In the summer the westerlies and easterlies are about equally frequent, but during the rest of the year, especially in the winter, the westerlies outnumber the easterlies. The east wind, known as the *Levanter,* is moist.

Winds in the Gulf of Lions. The winds are mainly from between north-west and north or between south-east and east. The northerly winds are more prevalent and include the north-west wind known as the *Mistral.* This wind often reaches gale force in winter and spring.

Winds off the North Coast of Africa between the Straits of Gibraltar and Sicily. In the west the winds are mainly westerly or easterly, the westerlies being more frequent in winter and about equal to the easterlies in summer. In the centre, westerly winds are more frequent in winter and easterlies in summer. In the eastern part north-westerly winds prevail the greater part of the year.

Winds in the Adriatic. The winds are variable. In the centre of this sea they alternate mainly between north-west and south-east in winter but in summer the north-west predominate. On the coasts the winds are mainly off shore in winter, and they tend to be on shore in summer. Among the off-shore winds, the north-east *Bora* is outstanding on the eastern shores. It often rises suddenly and reaches gale force.

Winds in the Central Portion of the Mediterranean. From the Malta Channel eastward the winds tend to be mainly north-west throughout the year, though the south-east *Scirroco* is frequent in autumn. A north-east wind known as a *Gregale* also occurs. In

the northern part of the Ionian Sea the winds in winter tend to alternate between north-west and south-east (parallel to the coast of Italy) ; but in summer the north-west winds predominate. In the Sea of Sidra the winter winds are mainly between north-west and west and the summer winds between north and north-east in the southern part.

Winds in the Eastern Portion of the Mediterranean. The winds are mainly north-west throughout the year except in the extreme east off the coasts of Palestine and Syria, where west and south-west winds predominate on the whole Gales come mainly from north-west in the southern part, and from between south-west and north-west and also from north-east in the vicinity of Cyprus.

BRITISH ISLES

The British Isles are situated in the region of the Westerlies, which blow between the parallels of 35° and 60°N. *Westerly winds* prevail, and cyclonic depressions generally approach the British Isles from the west.

Cyclonic Depressions, which cause gales, usually pass along the coast of Ireland and north-west of Scotland, and consequently the wind veers from south-east to south, south-west and west. It is by no means uncommon for these depressions to pass right across England. To the south of their tracks the wind veers from south-east to south, south-west and west, and to the north of their tracks it backs from east to north-east and north-west.

Gales are more frequent in winter, between October and March, and sometimes last four days. During May, June and July they are rare.

S.E. winds accompanied by rain and falling barometer often become gales, veering to south-west and west.

N.W. to N.E. winds, when moderate, bring fine weather.

Winds from north to north-east are sometimes strong, but seldom become gales in the central portion of the Channel, except on the French shore. They do not usually last for more than a day or two, and the wind generally backs from north-east to north, north-west and west.

Easterly winds are most common in spring.

Land and sea breezes frequently occur in summer. During the night the breeze falls light and there is heavy dew.

Calms are of rare occurrence, even in summer, and do not last long.

LOCAL WINDS

Full information concerning winds and weather in different parts of the world is given in *Ocean Passages,* the appropriate *Sailing Directions* and the ‘weather’ handbooks published for the various naval stations.

HUMIDITY

Between the particles of the air there are minute particles of water vapour which evaporation has released into the atmosphere, and the amount of water vapour in a unit mass of air at any moment is known as the [illegible]

Saturation. Warm air can hold more water vapour than cold air, and when the air contains the largest possible quantity of water vapour that it can hold without change of temperature, it is said to be saturated.

Relative Humidity. The proportion of moisture present in the air at any time to the total amount of moisture necessary for saturation is known as the *relative humidity,* and is expressed as a percentage. For any given amount of moisture in the air, the relative humidity therefore increases with a decrease in temperature.

Relative humidity is measured by means of a *psychrometer* (originally called a *hygrometer*).

The Psychrometer. A psychrometer consists of two ordinary thermometers placed side by side in a portable wooden screen, as shown in figure 147. One of the bulbs is covered with muslin that is kept continually moist by means of a strand of cotton wick, one end of which is immersed in a reservoir of fresh water. The screen should be placed in a position about 5 feet above the upper deck in the open air, as free as possible from radiation or warm draughts from galleys, engine and boiler rooms, and funnels. Since it is important that the temperature of the free air is obtained, the weather side is usually the best place for exposure.

All ships are supplied with a modified portable screen which can be conveniently hung up in any position.

The difference in temperature shown by the two thermometers is due to the loss of heat caused by the evaporation from the wet muslin, which, becoming cold, cools the mercury in the bulb. This evaporation is brisker as the dryness of the air increases, and therefore the difference between the two readings furnishes a fair guide to the humidity of the air.

The range is usually only a few degrees, but in very dry weather a range of as much as 25 degrees has been recorded.

Wick, water, and muslin should be scrupulously clean, and should, therefore, be frequently changed.

At least 15 minutes should elapse between mounting and reading, and if the clean water is not at the temperature of the air a much longer time is required.

In very cold weather evaporation will take place from the thin layer of ice formed on the surface of the wet bulb but at a different rate to evaporation off the surface of the water.

It sometimes happens that the wet bulb reads above the dry when the temperature is falling. The dry bulb follows the change

[*To face p.* 338.

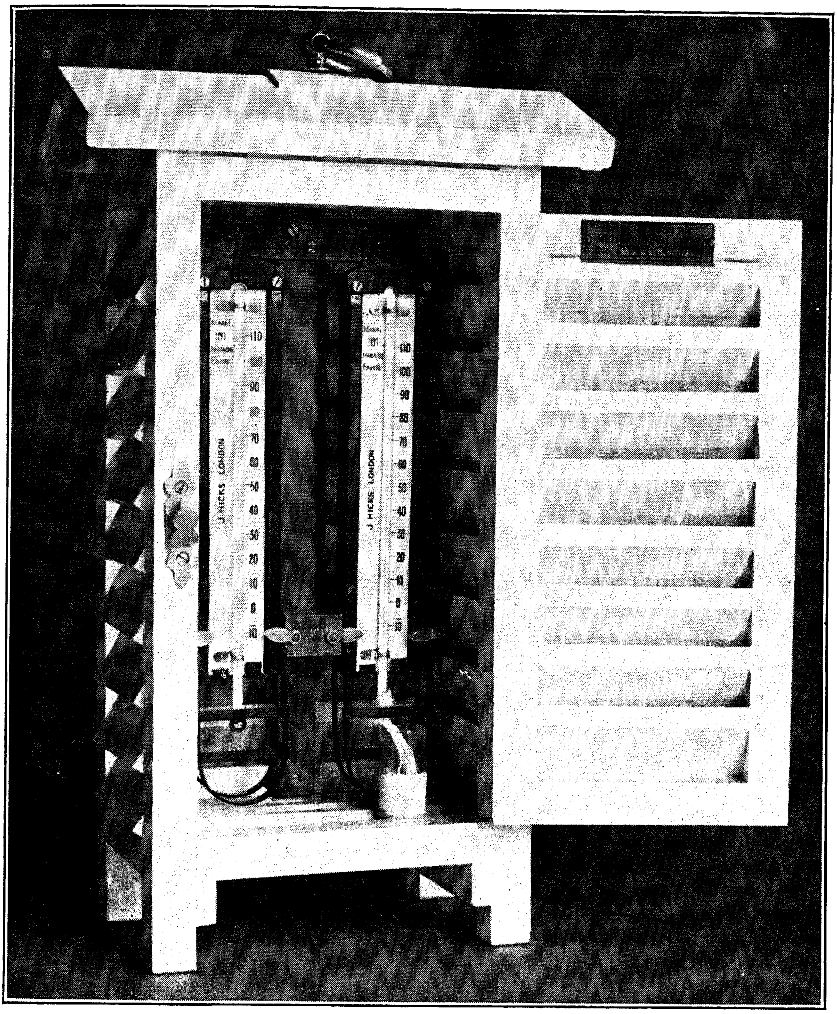


FIGURE 147.

of temperature with only a small time lag, but the wet bulb, being coated with muslin, has a greater lag; and if the temperature is falling sufficiently quickly, this may produce the result mentioned.

Where specially accurate data are required, the readings should be taken to 0°·1 F. by estimation, and the index errors of the thermometers should be applied. These errors are tabulated on a form supplied with each thermometer.

The relative humidity can be found from the readings of a psychrometer used in conjunction with the following table:

TABLE FOR FINDING THE RELATIVE HUMIDITY (PER CENT.).

Dry Bulb. °F.	Depression of Wet Bulb.												
	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
90	100	96	92	88	84	81	77	74	70	67	63	60	57
88	100	96	92	88	84	80	77	73	69	66	63	59	56
86	100	96	92	88	84	80	76	72	69	65	62	58	55
84	100	96	92	87	83	79	76	72	68	64	61	57	54
82	100	96	91	87	83	79	75	71	67	64	60	57	53
80	100	96	91	87	83	79	74	70	66	63	59	55	52
78	100	95	91	86	82	78	74	70	66	62	58	54	50
76	100	95	91	86	82	78	73	69	65	61	57	53	49
74	100	95	90	86	81	77	72	68	64	60	56	52	48
72	100	95	90	85	80	76	71	67	63	58	54	50	46
70	100	95	90	85	80	75	71	66	62	57	53	49	44
68	100	95	90	84	79	75	70	65	60	56	51	47	43
66	100	95	89	84	79	74	69	64	59	54	50	45	41
64	100	94	89	83	78	73	68	63	58	53	48	43	39
62	100	94	88	83	77	72	67	61	56	51	46	41	37
60	100	94	88	82	77	71	65	60	55	50	44	39	34
58	100	94	88	82	76	70	64	59	53	48	42	37	31
56	100	94	87	81	75	69	63	57	51	46	40	35	29
54	100	93	87	80	74	68	61	55	49	43	38	32	26
52	100	93	86	79	73	66	60	54	47	41	35	29	23
50	100	93	86	79	72	65	59	52	45	38	32	26	20
48	100	92	85	77	70	63	56	49	42	36	29	22	16
46	100	92	84	77	69	62	54	47	40	33	26	19	—
44	100	92	84	75	68	60	52	45	37	29	22	16	—
42	100	91	83	74	66	58	50	42	34	26	18	—	—
40	100	91	82	73	65	56	47	39	30	27	—	—	—
38	100	91	81	72	63	54	44	39	31	22	—	—	—
36	100	90	80	70	60	54	44	35	26	18	—	—	—
34	100	90	79	70	60	50	41	31	21	—	—	—	—
32	100	89	79	68	57	47	36	27	17	—	—	—	—
30	100	88	76	65	53	43	33	22	—	—	—	—	—

The values of relative humidity below the zig-zag line are valid only when the wet bulb is coated with ice. Interpolation should not be made across this line, but the values should be obtained by extrapolation downwards or upwards according as the wet bulb is water covered or ice covered.

NOTE. 1. If the two readings are the same, and the weather is not foggy, it is probable that the cistern is empty or that the dry bulb is coated with salt or dirt.

2. The instrument should frequently be examined to ensure that the cistern is full of pure water and that the bulbs, muslin and wick are clean.

3. The wet bulb temperature should never be logged as reading higher than the dry bulb.

4. Sometimes a broken mercury column may cause the wet bulb to read higher than the dry bulb. When this occurs the thermometer must be taken out and shaken.

DEW AND HOAR FROST

The temperature at which a mass of air reaches saturation is called the *dew point*. When through any cause the mass of air is chilled below the temperature of dew point, the water vapour, which can no longer be held in suspension, condenses. When it is condensed on blades of grass, the deck of a ship. etc., the deposit is known as *dew*.

If the dew point is below freezing point, the moisture is deposited in the form of *hoar frost*.

FOG AND VISIBILITY

Fog is formed by the condensation of water vapour on small hygroscopic particles or nuclei which are always present in the air. Over the land some of these nuclei are dust or smoke particles. Over the sea they mostly consist of salt crystals in the air, and these have such an affinity for water that they start to pick up moisture when the relative humidity is about 75%. When there is much spray there are more salt crystals in the air. Hence sea fogs are thicker nearer the land. Fog therefore depends upon the number of these nuclei in the air and upon the relative humidity.

The colder the air, the less moisture it can hold. If therefore, air, the relative humidity of which is high, is progressively cooled, it will sooner or later reach 100% relative humidity, that is, saturation or dew point, and any further cooling will condense some of the water vapour into visible drops.

The cooling of damp air is the primary cause of fog (or cloud), and upon the method of cooling depends the type of fog (or cloud) actually formed.

The 'lid' effect of an inversion, by which the lowest layer of air is prevented from rising, greatly facilitates the formation of fog because it keeps the same patch of air in contact with the cold Earth or sea.

When dust or smoke particles obscure vision in the surface layers, the reduction of visibility is known as *haze*.

Methods by which Damp Air is Cooled.

1. *Warm air passing over a cold surface. At sea,* when a warm moist wind blows over a colder sea surface, the damp air becomes

TABLE FOR FINDING THE DEW-POINT (°F.)

Dry Bulb. °F.	Depression of Wet Bulb. 0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
90	90	89	87	86	85	83	82	80	79	77	76	74	73
88	88	87	85	84	83	81	80	78	77	75	74	72	70
86	86	85	83	82	80	79	78	76	75	73	71	70	68
84	84	83	81	80	78	77	75	74	72	71	69	67	66
82	82	81	79	78	76	75	73	72	70	68	67	65	63
80	80	79	77	76	74	73	71	69	68	66	64	62	61
78	78	77	75	74	72	71	69	67	66	64	62	60	58
76	76	75	73	72	70	68	67	65	63	61	60	58	55
74	74	72	71	69	68	66	64	63	61	59	57	55	53
72	72	71	69	67	66	64	62	61	59	57	55	52	50
70	70	69	67	65	63	62	60	58	56	54	52	50	47
68	68	66	65	63	61	60	58	56	54	52	49	47	45
66	66	64	63	61	59	57	56	53	51	49	47	44	42
64	64	62	61	59	57	55	53	51	49	47	44	41	38
62	62	60	59	57	55	53	51	49	46	44	41	38	35
60	60	58	56	55	53	51	48	46	44	41	38	35	32
58	58	56	54	52	50	48	46	43	41	38	35	32	28
56	56	54	52	50	48	46	43	41	38	35	32	29	25
54	54	52	50	48	46	43	41	38	35	32	29	25	20
52	52	50	48	46	43	41	38	36	32	29	25	20	16
50	50	48	46	43	41	39	36	33	29	25	21	16	10
48	48	46	44	41	39	36	33	30	26	22	17	12	4
46	46	44	42	39	36	34	30	27	23	19	13	6	—
44	44	42	39	37	34	31	28	23	19	15	8	—	—
42	42	40	37	34	32	28	25	20	16	9	—	—	—
40	40	38	35	32	29	26	22	17	11	8	—	—	—
38	38	35	33	30	26	22	18	15	10	3	—	—	—
36	36	33	30	27	23	21	16	11	5	—	—	—	—
34	34	31	28	25	22	17	13	7	—	—	—	—	—
32	32	29	26	22	19	14	8	—	—	—	—	—	—
30	30	27	23	20	15	10	4	—	—	—	—	—	—

cooled. About 90% of sea fogs in all parts of the world are formed in this manner. These conditions are most marked when a cold ocean current is forced to the surface; the Davis Strait current on the Newfoundland banks, for example.

On land, the damp air becomes cooled when conditions are suitable for radiation. During the day the air is heated and able to continue absorbing moisture. At night, if the sky is cloudless, the Earth radiates its heat into space and becomes cool, thus cooling the surface air below its dew point and, if there is a gentle breeze, forming fog.

The clear skies and light winds necessary for pronounced radiation occur most frequently in anticyclones, but sometimes also in wedges and on the rear side of depressions.

Since the air in both these circumstances is colder than that above it, it cannot rise; that is, there is an inversion.

2. *Cold air passing over warm water.* In these circumstances two processes occur. First the cold air absorbs moisture by direct evaporation from the warm water, and secondly the lowest layers of the cold air are heated by contact with the warm water and so tend to rise. As soon as the air rises it meets air which is colder than itself. The rising air is then chilled below the dew point and fog is formed. The fog is unlikely to reach any appreciable height before the surplus moisture is absorbed by the colder and drier air. This form of fog is therefore usually low lying, and a lookout placed at the masthead will probably be able to see over it.

In Great Britain and lower latitudes, fogs from this cause are rare. In Arctic regions, however, they are common. The sea appears to steam and the phenomenon is called *Arctic sea smoke.* The steam over a hot bath or cup of tea is an example of this type of fog.

Propagation of Fog. Fog can propagate itself in two ways:

1. *By radiation.* The water drops at the top of the fog radiate their heat and, becoming colder, cool the air in contact with them below dew point, thus forming more fog.

2. *By slight increase in wind force.* This, by mixing air of different temperatures, may cause more fog.

Dissipation of Fog. Fog can be dissipated in three ways:

1. *By heat.* The heat of the Sun warms the surface of the Earth below the fog. The Earth then heats the surface air in contact with it and the fog starts to disappear.

The Sun is able to do this about two hours after sunrise.

A similar effect occurs when a fog drifts over a warm patch of water or meets a warm ocean stream.

The surface air in contact with the warm water becomes heated and the fog begins to disappear. This form of dissipation must not be confused with Arctic sea smoke.

2. *By considerable increase in the strength of the wind.* In these circumstances the various layers, some of which are being heated by the Sun, become mixed, so that eventually the temperature of

the mixed air will be raised above dewpoint and the inversion will probably disappear.

3. *By a change in direction or a new source of the wind.*

Locality. Full details are given in the various *Sailing Directions*. The following table shows the important localities where fogs are frequent, and the seasons at which they occur:

Locality	*Season*
British Islands.	At all seasons, but most frequently in the Channel during late spring and early summer.
West Coast of Africa, North of the Equator.	November to May.
West Coast of Africa, South of the Equator.	June to August.
West Coast of North America.	Very frequent in summer.
Banks of Newfoundland.	At all seasons, but most frequently in June and July.
Coast of China.	January to April.
Japan.	April to June.

CLOUD

Cloud is formed by the condensation of the water vapour in the atmosphere at a height above the Earth's surface.

The method by which the air is cooled or raised up and the height at which condensation takes place depends on the general atmospheric conditions and the relative humidity respectively.

High Clouds are fleecy and usually more or less transparent. They are known as *Cirrus* and are composed of ice crystals formed by the condensation of water vapour at a very low temperature. There are various forms of cirrus cloud found between heights of 20,000 and 30,000 feet.

Middle Clouds are between 8,000 and 20,000 feet and consist of the high *Cumulus* and high *Stratus* type. (*Alto Cumulus* and *Alto Stratus*.)

Low Clouds below 8,000 feet include *Cumulus* or the woolpack cloud, and *Stratus* or the sheet cloud.

Table of Clouds

Form of cloud	*Usual Height of base*	*Remarks*
Stratus .. (St)	500–2,000 ft.	Sometimes practically down to the surface; sometimes as high as 4,000 ft.
Strato cumulus (StCu)	1,500–4,500 ft.	Sometimes as low as 500 feet; or as high as 8,000 feet.

Table of Clouds—*continued*

Form of cloud		*Usual Height of base*	*Remarks*
Cumulus	(Cu)	2,000–5,000 ft.	Sometimes as low as 1,000 feet or as high as 8,000 feet.
Cumulo nimbus	(CuNb)	2,000–5,000 ft.	As Cumulus. The top of CuNb frequently extends to over 10,000 feet and may reach 25,000 feet.
Nimbo stratus	(NbSt)	500–2,000 ft.	Sometimes practically down to the surface; sometimes as high as 4,000 feet.
Alto stratus	(A St)	Usually between 6,500 and 20,000 ft.	
Alto cumulus	(A Cu)		
Cirrus	(Ci)	Usually between 20,000 and 40,000 ft.	In the tropics the upper level may be 50,000 ft. or more.
Cirro cumulus	(CiCu)		
Cirro stratus	(CiSt)		

Rain. Rain is the result of further condensation of the water vapour within a cloud. When the temperature of the atmosphere, by its expansion in ascending, is lowered below the point of saturation or dew-point, the minute spherical drops of water, of which cloud is composed, are increased in size and weight by a further condensation of water vapour and also by the union of several drops. Finally they become too heavy to be supported in the air and start to fall as rain.

Hail. Hail is formed by the freezing of rain drops held in suspension. This occurs when strong convectional currents carry the rain drops to great heights where they freeze and eventually fall as balls of ice.

Snow. Snow is formed by the condensation of water vapour at a temperature below freezing point in the form of ice crystals.

Sleet. Sleet is the name given to falling snow which has been almost melted by passage through the warmer surface layers.

Lightning and Thunder. When the raindrops in a cloud are swept upwards by a rising current of air, they increase in size. This increase, however, is not indefinite. When it reaches $\frac{1}{4}''$ in diameter, the raindrops disintegrate. This action liberates an electrical charge which in time causes a difference of potential between the top and bottom of the cloud large enough to cause a discharge. The discharge may take place between the cloud and the Earth, or between two clouds, and if it is visible it is known as *forked lightning*. If the reflection only can be seen it is known as *sheet lightning*.

The noise of the expansion and consequent contraction of the air due to this discharge is called *thunder*.

TROPICAL REVOLVING STORMS

(See figures 149 and 150)

A pamphlet, M.O.404a, describing typhoons in detail, is published by H.M. Stationery Office.

Tropical revolving storms are called *cyclones* in the Indian Ocean, *hurricanes* in the West Indies and South Pacific, and *typhoons* in the China Seas. They are unknown in the South Atlantic.

The strongest winds at sea are encountered in tropical revolving storms. These storms usually consist of deep low-pressure areas, with centres of comparative calm where the barometer is always lowest. The *centre* is sometimes called the *vortex* or the *eye of the storm*. In this centre, which has been found to average about 8 miles in diameter, the wind is variable, light or calm, but there is a tremendous cross sea, which is extremely dangerous because it runs in all directions.

Round this region of calm there is a belt of winds of hurricane force blowing spirally towards the centre; anti-clockwise in the northern hemisphere, and clockwise in the southern hemisphere.

Over the whole disturbance there is usually much low cloud and torrential rain with poor visibility.

When the centre approaches a ship she may experience increasing winds with violent squalls, later increasing to hurricane force with mountainous seas. As the vortex passes over her, the wind drops. When it has passed the wind may suddenly come from the opposite point of the compass with renewed violence, beginning with a terrific squall which is particularly dangerous to ships at anchor because they may be caught with the squall abeam. As the storm recedes from the ship the wind moderates, as shown in figures 149 and 150. Thunder and lightning may be experienced.

NOTE. In the centre of the storm the sky is much brighter and blue sky may appear through rifts in the clouds.

Formation. Tropical revolving storms depend on warm moist air for their formation and originate between latitudes 10° and 20° either side of the equator at the boundary between the N.E. or S.E. Trades and the Doldrums, except in the China Sea where they sometimes form at a lower latitude in winter and a higher latitude in summer.

They seldom, if ever, originate over the land, and if they reach the coast they weaken, lose their destructive violence and are soon transformed into ordinary depressions or die out altogether, because the sea alone can supply the warm moist air necessary to feed the energy of the whirl.

The storm field may have a diameter of several hundred miles, increasing as the storm progresses to higher latitudes where the diameter of the same storm may be over 1,000 miles. The diameter of the belt of wind of actual hurricane force has been found to vary

APPROXIMATE WIND FORCE IN A TROPICAL REVOLVING STORM

NORTHERN HEMISPHERE

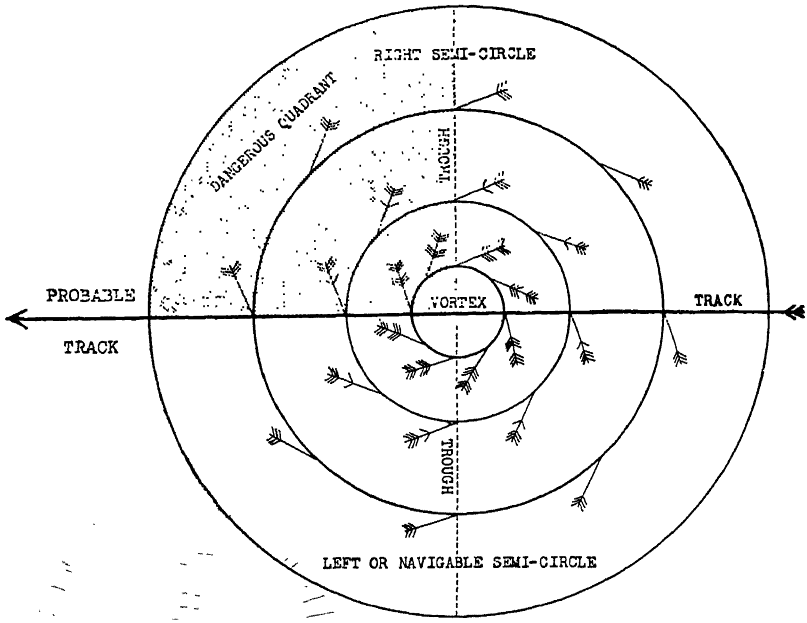


FIGURE 149.

SOUTHERN HEMISPHERE

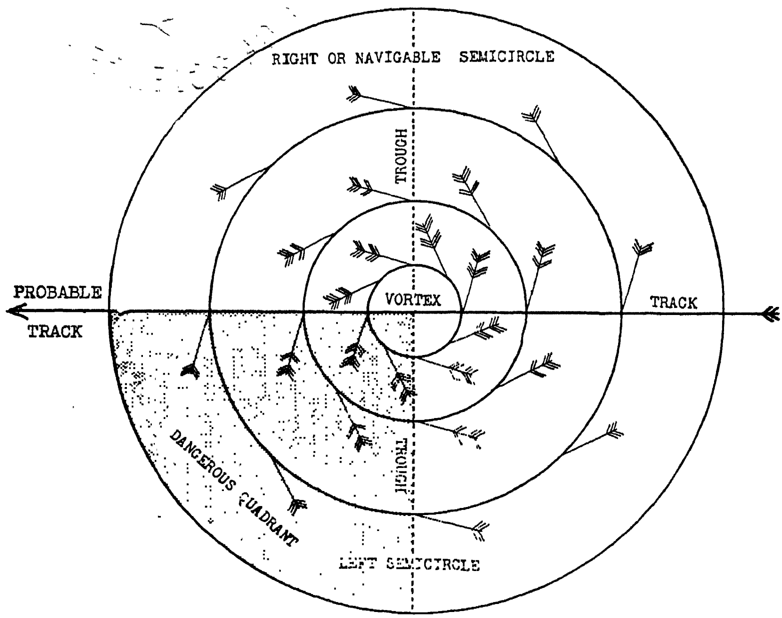


FIGURE 150.

between 5 and 65 miles, and the width is sometimes found to be greater in rear of the centre than in advance of it.

It is probable that these dimensions are exceeded in some revolving storms.

The influence of a tropical revolving storm is probably felt at heights exceeding 15,000 feet.

The Track. In addition to their circular motion, tropical revolving storms have a forward or progressive motion. At first moving westward with gradually increasing speed, they often travel round the western edge of the great ocean anti-cyclones, recurving, on an average, in latitudes 30°N. and 25°S.

The following is a rough estimate of the progressive speed of tropical revolving storms :

Latitude 10°	.. 6 to 8 knots
,, 20°	.. 12 knots
,, 28°	.. 15 to 20 knots
Higher latitudes ..	.. up to 50 knots

During this recurving their progressive motion slackens, but after curving back they travel north-east or south-east, according to the hemisphere, and pass into middle latitudes, expanding and travelling at great speed.

NOTE. Some tropical revolving storms have erratic tracks, whereas the tracks of cyclones in the Bay of Bengal and the Arabian Sea are straight.

The Vertex, sometimes called the *cod of the track,* is the most westerly point reached by the centre of the storm before it curves back.

The Right Semicircle is that half of the storm which lies to the right of an observer looking along the track.

The Left Semicircle is that half of the storm which lies to the left.

The Navigable Semicircle is that semicircle which lies on the side of the path furthest from the normal direction in which the path recurves.

The Trough is a line drawn through the centre at right-angles to the probable track.

The Dangerous Quadrant is the advanced quadrant of that semicircle which lies on the side of the path nearest to the normal direction in which the storm recurves, so named because a ship caught in the dangerous quadrant may be blown towards the track of the storm-centre or the path may recurve and pass over her.

The Angle of Indraft is the angle which the direction of the wind makes with an isobar.

Thus in north latitude, if, near the centre, the wind blows

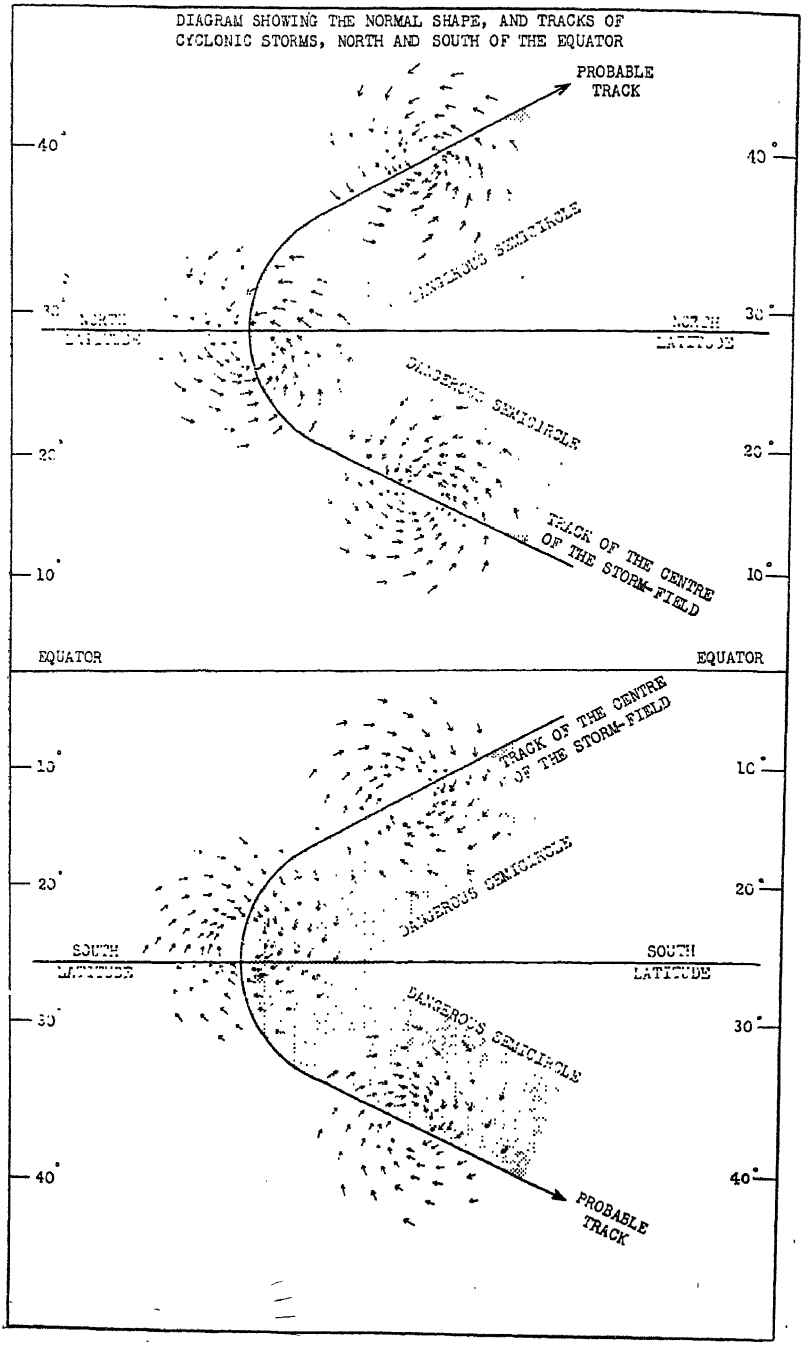


DIAGRAM SHOWING THE NORMAL SHAPE, AND TRACKS OF
CYCLONIC STORMS, NORTH AND SOUTH OF THE EQUATOR
PROBABLE TRACK
40°
30°
20°
10°
DANGEROUS SEMICIRCLE
TRACK OF THE CENTRE OF THE STORM-FIELD
EQUATOR
SOUTH LATITUDE
PROBABLE TRACK

FIGURE 151.

along an isobar and the centre bears 8 points to the right when an observer faces the wind, there is said to be no indraft; or, if the wind blows at an angle of 2 points to an isobar, and the centre bears 10 points to the right of an observer facing the wind, the indraft is said to be 2 points. It must, however, be remembered that isobars in these storms are not always circular, and the angle of indraft may not therefore be the angle of the bearing of the centre minus 8 points.

Comparative Table Giving Details of Various Atmospheric Disturbances

Disturbance	*Diameter of area covered*	*Duration*	*Maximum wind speed*
Normal depression	1,500 miles	Several days	100 knots
Cyclone, hurricane or typhoon.	20 to 300 miles	,, ,,	150 knots
Tornado	Less than one mile	One to two hours	300 knots
Waterspout	3 to 30 feet	Several minutes	—

WARNING SIGNS

(Extracts from M.O.404a published by H.M. Stationery Office)

1. **Swell.** In the open sea, if there is no intervening land between the ship and the centre, the swell will probably give the first indication of a tropical revolving storm.

The swell may extend to a distance of over 1,000 miles from the actual storm and can usually be relied on to make itself felt 400 miles from the centre of the storm. The swell moves out from the centre of the storm, and its direction thus gives a good idea of the bearing of the centre.

When the storm is at a greater distance than 200 miles from a ship, the direction of the swell is the most reliable of all indications of the direction in which the centre lies.

Although the swell increases as a storm approaches, its state does not give any reliable indication of the distance of the centre.

2. **Barometer.** Although the barometer cannot be relied on to give adequate warning of the approach of a storm on all occasions, it assists when considered in conjunction with other precursory signs. On many occasions the barometer will be unsteady when a storm approaches, but the barometer is often unsteady on other occasions, notably during tropical thunderstorms and summer squalls. Moreover the barometer is not always unsteady when a storm is approaching.

Over the sea away from large land areas, for example, to the east of the Philippines, the mean pressure varies little from day to

day and therefore any variation (even of one or two millibars) from mean pressure should be regarded with suspicion.

In ideal circumstances, and on occasions when a typhoon is going to pass reasonably close to the observer, there are usually three fairly definite phases in the fall of the barometer :

(a) A slow fall during which the diurnal variation is still apparent on the barograph trace. This usually occurs between 500 and 120 miles from the centre of the storm.

(b) A distinct fall during which the diurnal variation is almost completely masked. This usually occurs between 120 and 60 miles from the centre. Throughout this phase the barometer is sometimes very unsteady.

(c) A rapid fall. This usually occurs between 60 and 10 miles from the centre.

In the rear of the storm the barometer rises as rapidly as it fell in advance of the storm.

It is not uncommon for the barometer at the centre of a storm to stand 60 to 70 mb. lower than in the region just outside the storm field. The steepest barometric gradient normally met with is 11 mb. in 15 miles.

3. **Clouds and General Weather.** Cirrus clouds generally, but not always, precede a storm. In the tropics, if cirrus stretches in convergent streaks or bands, and the convergent formation remains visible in a fixed direction, it is a fairly good warning, and the centre of the storm probably lies in the direction of the point of convergence. Such a formation may appear as much as 500 miles ahead of the centre.

The cirrus clouds associated with a storm sometimes cause the most lurid sunsets and sunrises. A fiery copper-coloured sky is not uncommon, but any or all colours of the rainbow may be visible. On many occasions, however, no such striking display appears in advance of a typhoon.

The weather is usually sultry and oppressive and there is an indefinite feeling that all is not well.

At, on the average, 100 to 150 miles from the centre, heavy continuous rain sets in, and a little later becomes torrential. As the centre passes, heavy continuous rain, just as heavy as that which preceded the storm, again sets in but it probably does not last so long, because the rain area in the rear of a storm is generally a good deal smaller than the area in front of it.

W/T WARNINGS

In all oceans reliable warnings are now sent out by shore stations by W/T. For example :

Broadcast from Hong Kong—‘ Typhoon of unknown intensity situated within 50 miles of latitude 19°N., longitude 121°E. moving north-west.’

PRACTICAL RULES FOR AVOIDING TROPICAL STORMS

If from the above signs there is reason to suppose a storm is approaching, it is necessary to know:

1. the direction in which the centre of the storm lies.
2. in which semicircle the ship is situated.

These positions are determined by observing the wind shift, but it must be remembered that the wind to be considered is the true wind and it will be necessary to allow for the ship's speed which causes the wind that is felt.

To Find the Bearing of the Centre. Face the wind and the centre of the storm will be from 12 to 8 points on the right hand in the northern hemisphere, and on the left hand in the southern hemisphere; 12 when the storm begins; about 10 points when the barometer has fallen 10 mb., and about 8 points when it has fallen 20 mb. or more.

To Find in which Semicircle the Ship is Situated. Face the wind and if it shifts to the *right* the ship is in the *right-hand* semicircle, if to the *left* in the *left-hand* semicircle.

If the barometer is *falling*, the ship is *before* the trough of the storm; and if it is rising, the ship is to the rear of the trough.

It is not possible to estimate the distance of the centre of the storm from a vessel. This arises partly from uncertainty about the relation between the bearing of the centre and the direction of the wind, but mainly because there are no means of knowing whether the storm is large or small. If the barometer falls slowly and the weather gradually gets worse, it is reasonable to suppose that the centre is distant, and conversely, with a rapidly falling barometer and increasing bad weather, the centre may be supposed to be dangerously near.

If the wind remains steady in direction but increases in force, with a falling barometer, the ship is in the direct path of the storm, which is the most dangerous position of all.

The above laws hold good for both hemispheres.

The following are the most advisable courses to pursue to avoid the centre:

If in the path of a storm, run with the wind on the *starboard quarter* in the *northern hemisphere,* and on the *port quarter* in the *southern hemisphere,* away from and at right angles to the assumed path of the storm, until the barometer begins to rise.

If in the dangerous semicircle (that is the *right-hand semicircle* in the *northern hemisphere* and *left-hand* in the *southern hemisphere*), a *steam vessel* should *steam to windward* away from and at right angles to the assumed path of the storm. A *sailing vessel* should *heave-to* on the *starboard tack* in the *northern hemisphere,* and on the *port tack* in the *southern hemisphere,* because the wind will then always be drawing aft. Be careful to note the land and navigational dangers in the vicinity, because it may be possible to run into

harbour, or under the lee of the land, for shelter, but in some circumstances it is better to remain at sea.

If in the navigable semicircle (that is *left-hand semicircle* in the *northern hemisphere*, and *right-hand* in the *southern hemisphere*), *run with the wind* on the *starboard quarter* in the *northern hemisphere*, and on the *port quarter* in the *southern hemisphere*, away from and at right angles to the assumed path of the storm, until the barometer begins to rise.

It is better to proceed at full speed ahead of the cyclone into some recognised ' typhoon anchorage ' than to be caught in narrow waters, because the visibility becomes very low, due to driving rain and spray, and quite large sets are experienced.

If in harbour or at anchor, watch carefully the shifting of the wind and ascertain the direction of the centre and on which side of the path of the storm the ship is situated so that if the centre passes over the ship it may be possible to point ship in the direction of the coming squall.

Storm Tides. When a cyclone approaches a coast, serious flooding often occurs. The largest waves originate in the rear right-hand quadrant and travel through the cyclonic area, eventually reaching the shore where they cause a rise in the water in front of, and 100 to 200 miles to the right of, the line of advance of the storm. This rise begins when the centre of the cyclone is 300 to 500 miles away and continues until the cyclone crosses the coast. The height of the flood level reached at the shore near the centre of the storm is sometimes as much as 15 feet above the predicted tide level.

Slow-moving storms of large diameter create the highest tides.

Seasons during which Tropical Revolving Storms Occur. Tropical revolving storms occur at definite seasons in different parts of the world.

West Indies ..	Hurricanes may blow here from June to November. They are most frequent during September and they generally curve to the northward by the Bahamas and between the American coast and Bermuda. Some pass to the Gulf of Mexico and curve across the United States of America; others curve northward well out into the Atlantic, eastward of Bermuda.
South Indian Ocean	Cyclones blow here from October to June. They are most frequent from December to April.
China Sea	Typhoons may blow here during all months of the year. They are most frequent during October and they generally move in a west or north-west direction at first, finally curving north or north-east.

Arabian Sea Cyclones blow here from April to January. They are most frequent during June, October and November, and seldom blow during August. They originate near the Laccadives.

Bay of Bengal Cyclones blow here from May to December. They are most frequent during September and originate near the Andaman Islands and generally travel to the north-west or north-east, sometimes crossing India.

South Pacific Hurricanes blow here from December to April. They are most frequent from January to March.

North Pacific Hurricanes may blow here during all months of the year. They are most frequent from July to October.

Rate of Progression of Tropical Revolving Storms. The rate of progression of tropical revolving storms varies, but the average daily movement in different localities is :

West Indies	.. 300 miles.
South Indian Ocean ..	.. 50 to 200 miles.
China Sea	.. 200 miles.
Arabian Sea	.. 200 miles.
Bay of Bengal ..	.. 200 miles.

Frequency. The following table gives the number of tropical revolving storms in each month over a long period of years.

	J.	*F.*	*M.*	*A.*	*May*	*J.*	*Jy.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Av. No. per year*
West Indies	0	0	0	0	1	16	17	39	78	71	15	2	7
S. Indian Ocean ..	113	115	98	68	25	3	2	0	0	7	33	58	8
Bombay ..	1	1	1	5	9	2	4	5	8	12	9	5	3
China Sea	9	2	5	10	25	41	74	74	88	65	51	24	22
Arabian Sea	2	0	0	2	5	11	3	0	2	10	8	2	2
Bay of Bengal	0	0	0	7	21	42	65	55	70	51	37	17	10
S. Pacific	69	48	64	18	2	2	1	1	2	4	8	31	7

CHAPTER XIV

SYNOPTIC CHARTS AND WEATHER FORECASTING

A weather forecast is achieved by considering the different types of air masses, their effect on one another, and the weather consequently produced.

Day-to-day weather forecasts are prepared with the aid of weather maps or synoptic charts. A weather map of any area is an outline chart on which are written symbols indicating the state of the weather at a number of stations covering that area. These comprise land stations, lighthouses, lightships and sea-going vessels. The international grouping of these stations, the information sent out and the method of plotting synoptic charts is fully dealt with in the *Weather Manual*, and only a brief description is given in this Chapter.

AIR MASSES

Air masses can be divided into two main types:

1. *Polar air* originating in Arctic regions. Polar air may be modified as it travels:

   (*a*) over the sea, where it is called *maritime polar air*.
   (*b*) over the land, where it is called *continental polar air*.

2. *Warm, tropical or equatorial air.*

CHARACTERISTICS OF POLAR AND TROPICAL AIR MASSES ON ARRIVAL IN TEMPERATE LATITUDES

Tropical air, as it travels north, passes over a sea surface that is continually getting colder. The bottom or surface layers are therefore cooled and the air becomes stable. The opposite occurs when polar air travels south over surfaces that grow continually warmer. The bottom layers are heated and the air becomes unstable. Clearly, then, the surface temperature of polar air may differ only slightly from the surface temperature of tropical air.

Polar Air

(*a*) In the upper air, at any particular level, the temperature is low and the atmosphere therefore unstable.

(*b*) Clouds are cumulus or cumulo-nimbus, except in maritime polar air where they are usually strato-cumulus.

(*c*) There is good visibility.
(*d*) The relative humidity is low.
(*e*) Winds are squally and usually from a northerly direction.
(*f*) Rain is in the form of showers.
(*g*) The temperature of the air is less than the temperature of the sea.

Tropical Air

(*a*) In the upper air, at any particular level, the temperature is high and the atmosphere therefore stable, particularly in the lower levels.
(*b*) Clouds are of the stratus type.
(*c*) Visibility is low with a tendency for fog.
(*d*) The relative humidity is high if the air mass has been passing over water.
(*e*) The wind is usually from the south-west quadrant and there are no squalls.
(*f*) Rain is in the form of drizzle.
(*g*) The temperature of the air is greater than the temperature of the sea.

FORMATION AND DISSIPATION OF DEPRESSIONS

When two air streams of different origins and properties converge, they do not flow side by side without interaction. Each encroaches on the other so that kinks or waves develop on the line of demarcation between them. This line of demarcation between polar and tropical air is called the *polar front*.

When one of these kinks develops, various phenomena occur.

1. The warm air rises over the cold air and causes an area of low pressure to develop, usually at the top of the kink. This, in turn, causes a cyclonic circulation of wind round the area of low pressure. The cold air is thus deflected round and, coming in behind the kink, encroaches on the warm air and forces its way underneath. The line where this occurs is called the *cold front* and is shown in blue in figures 152 and 153.

2. On the opposite side of the kink, where the warm air is encroaching on the cold air and rising over it, the line of demarcation is called the *warm front*, shown in red in the same figures.

3. The cold front travels faster than the warm front, and a time comes when the cold front overtakes the warm front and all the air in the original warm sector is lifted up and *occluded*, as shown in figures 152 and 153. When this occurs the source of energy is removed and the depression gradually expends itself. It is then said to have ‘ filled up ’.

The whole disturbance can be considered as moving along the polar front like a tidal wave. Its speed varies with the initial energy of the disturbance and sometimes reaches 70 knots, though the average speed can be taken as about 25 knots.

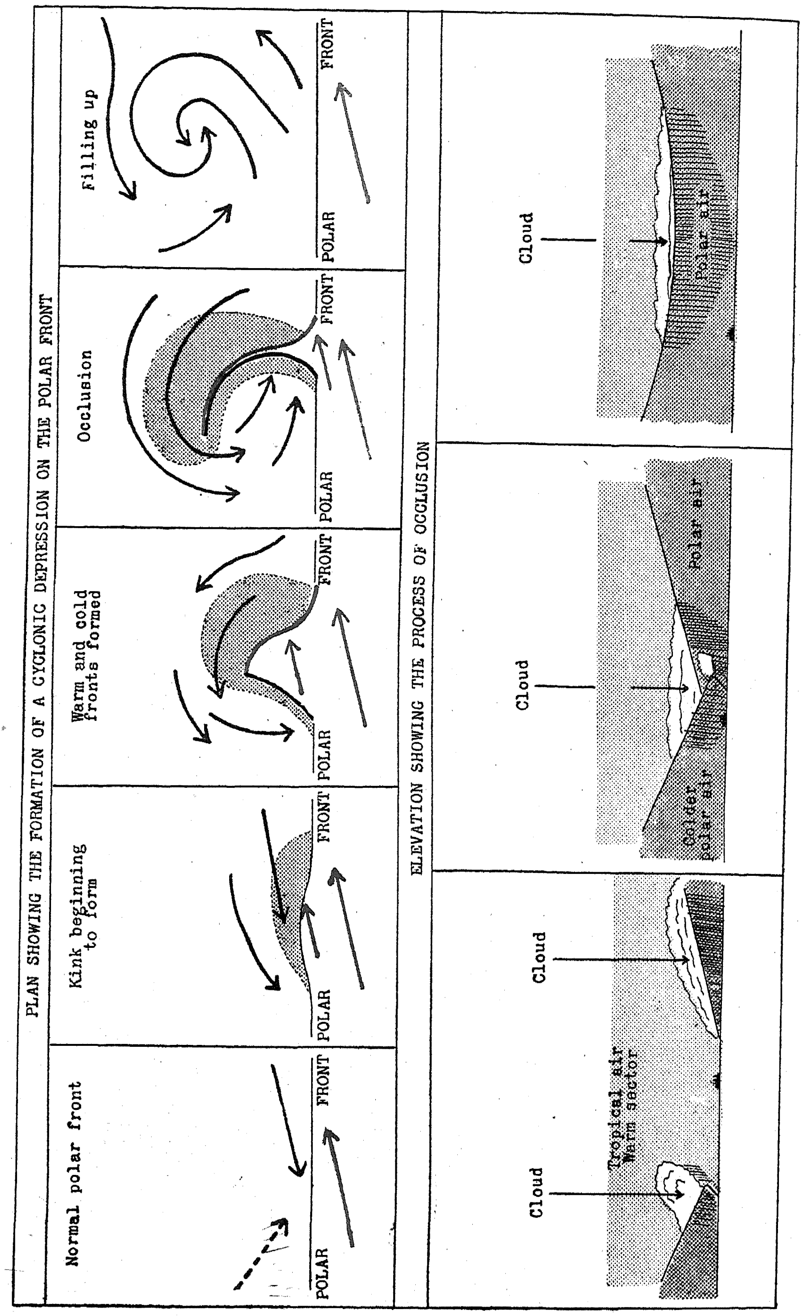

PLAN SHOWING THE FORMATION OF A CYCLONIC DEPRESSION ON THE POLAR FRONT
Normal polar front
Kink beginning to form
Warm and cold fronts formed
Occlusion
Filling up
POLAR FRONT
POLAR FRONT
POLAR FRONT
POLAR FRONT
POLAR FRONT
ELEVATION SHOWING THE PROCESS OF OCCLUSION
Cloud
Cloud
Tropical air
Warm sector
Cloud
Colder polar air
Polar air
Cloud
Polar air

FIGURE 152.

CYCLONIC DEPRESSION

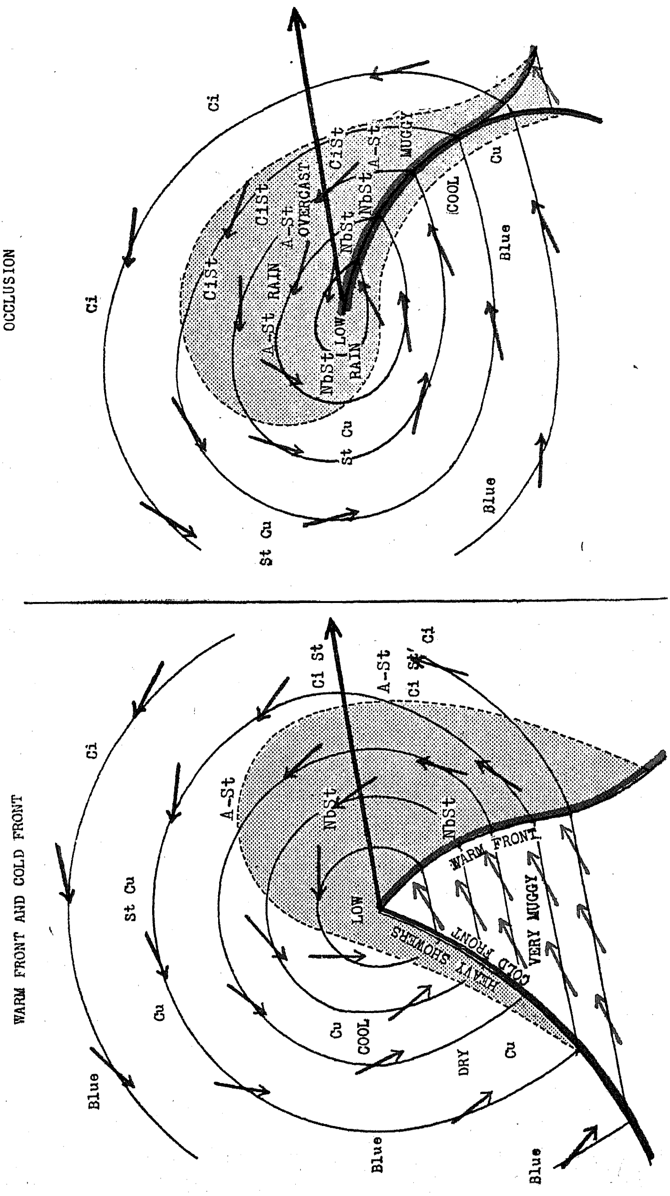


FIGURE 153.

CHANGES IN WEATHER ON THE ARRIVAL OF FRONTS

This table assumes the depression to be travelling on an easterly course.

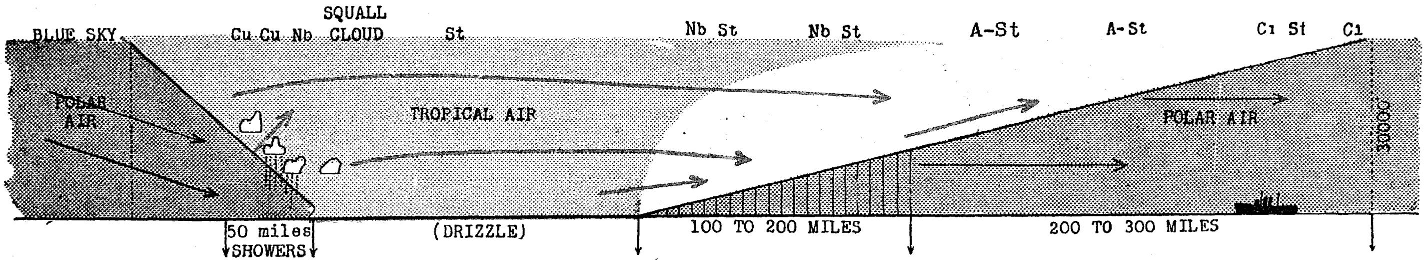
	Warm Front	*Cold Front*	*Occlusion*
Wind ..	Veers from S. to S.W. and increases.	Veers from S.W. to W. or N.W. with squalls, and decreases in force.	S.W. to W. or N.W.
Barometer	Falls rapidly before the front. The rate of fall decreases after the passage of the front.	Is steady or shows a slow fall before the front followed by a sudden rise when the front has passed.	A sudden rise.
Temperature	Warmer	Cooler	Little change.
Relative humidity.	Increases. A greater increase when the front has passed.	Decreases. Much lower when the front has passed than before the front arrived.	Similar to a cold front but not so marked.
Visibility ..	Deteriorating ..	Great improvement after the front has passed.	Improving. Clearer than in warm air.
Sky ..	Becoming overcast in the order Ci., CiSt., ASt., NbSt. before the front. After the front has passed St.	StCu. and CuNb., when the front is passing, followed by Cu., and blue sky.	A St. and NbSt. followed by StCu., CuNb. and Cu. with blue sky.
Rain ..	Continuous rain either ceasing on the arrival of the front or becoming drizzle, either continuous or intermittent.	A narrow belt of heavy showers and possible thunderstorms. Lighter showers later.	Continuous rain until the front passes, after which occasional showers may be expected.
Upper air	Stable	Unstable	Unstable.

The changes can be summarised as :

1. a veer in wind direction and possibly a change in strength.
2. a rain belt.
3. an alteration in the sky.
4. a change of temperature.
5. an alteration in the rate of change of the barometer.
6. a change of relative humidity.

Figure 154 illustrates the sequence of weather on the passage of warm and cold fronts.

THE SEQUENCE OF WEATHER ON THE PASSAGE OF WARM AND COLD FRONTS



TROPICAL AIR

1. Stable in the Lower Layers.
2. Stratus Cloud.
3. Low Visibility. Tendency for Fog.
4. High Relative Humidity if the air has passed over Water.
5. No Squalls. Wind usually in the South-West Quadrant.
6. Rain in the form of Drizzle.
7. Air Temperature greater than the Sea Temperature.

POLAR AIR

1. Unstable in the Lower Layers.
2. Cumulus or Cumulo Nimbus Cloud.
3. High Visibility.
4. Low Relative Humidity.
5. Winds Squally. Usually in the North-West Quadrant.
6. Rain, if any, in the form of Showers.
7. Air Temperature less than the Sea Temperature.

FIGURE 154.

THE FORMATION OF SECONDARIES

When a depression is occluded, its speed of advance is reduced and it may even stop. When this occurs secondary disturbances are liable to form on the warm side of the depression. They will rotate round the parent depression, bringing with them similar changes of weather, usually on a smaller scale. Sometimes the only effect is that the barometer ceases to rise and there is a temporary reversion to an overcast sky with little or no rain. A secondary depression may, however, develop to a considerable extent and become as deep as its parent and cause much rain and wind.

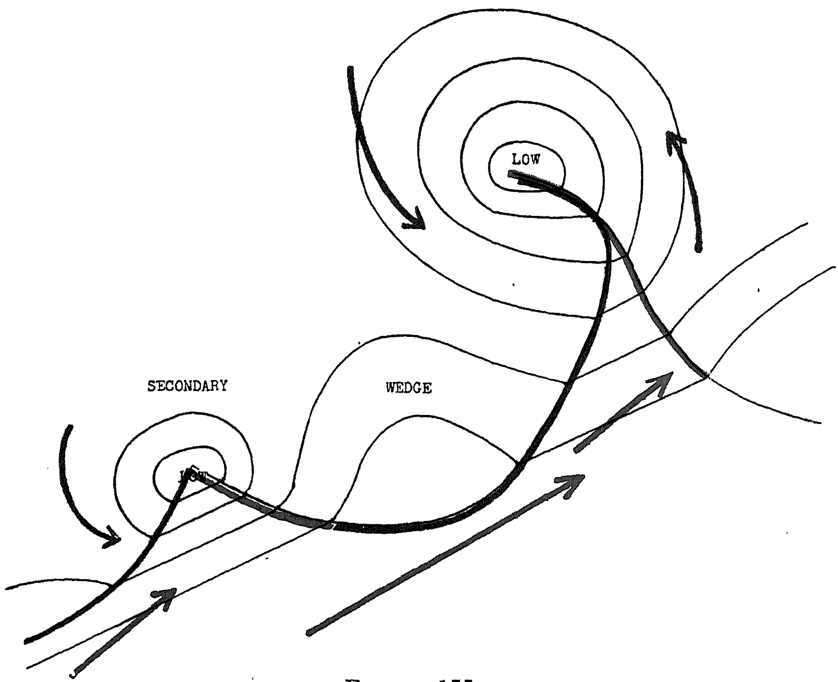


FIGURE 155.

Figure 155 shows a secondary depression following its parent depression.

THE MOVEMENT AND DEVELOPMENT OF DEPRESSIONS

On a weather chart, a depression appears as a system of closed isobars with the lowest pressure in the centre.

Various points should be noted when their movement and development are considered.

1. They usually move from south of west to north of east in the Eastern North Atlantic and Western Europe.

2. Over the sea, a depression that has been moving in a certain direction for a period of twelve hours will probably continue to move in approximately the same direction for the following twelve hours unless it meets land during this time.

3. The track is usually parallel to the isobars in the warm sector.

4. The probable movement will be :

(*a*) towards the place where the barometer is falling most rapidly.

(*b*) away from the place where the barometer is rising most rapidly.

5. If the barometer is rising behind a depression more rapidly than it is falling in front of the same depression, the probability is that the depression is filling up and slowing down.

6. If the barometer is falling in front of a depression more rapidly than it is rising behind the same depression, the probability is that the depression is deepening and increasing the speed of advance.

7. If two depressions of similar intensity are adjacent they will, in the northern hemisphere, rotate anticlockwise round each other, eventually combining into one single depression.

8. When meeting land, depressions are frequently slowed down and eventually fill up because there is no longer a plentiful supply of warm moist air.

WEDGES

A wedge, as shown in figure 155, is the area of relatively high pressure between two depressions which usually brings a brief spell of fine clear weather.

ANTICYCLONES

On a weather chart an anticyclone, like a depression, appears as a system of closed isobars, but with the highest pressure in the centre, as shown in figure 156.

The isobars are, normally, farther apart than in a depression, an anticyclone being a region of light winds. The movement of anticyclones is usually slow and irregular ; they sometimes remain without any appreciable change of position for several days.

The weather is usually fine, but in winter, particularly in the southern half of the anticyclone, the sky may be overcast when the wind has travelled over the sea.

The absence of strong winds and the stable conditions of the atmosphere are very favourable for the formation of fog over the land, and most of the fogs in autumn and winter occur during anticyclones.

NOTE. When a depression travelling along the polar front meets an anticyclone it must either stop or be deflected. Usually, when this occurs, the depression either fills up or turns north.

COLS

A col, as shown in figure 156, is a region of relatively low pressure between two anticyclones. Since in this area there will often be two air streams of different origins adjacent to each other, the weather will be unsettled, and fog and mist can be expected in winter or sultry weather with a possibility of thunderstorms in summer.

ANTICYCLONES

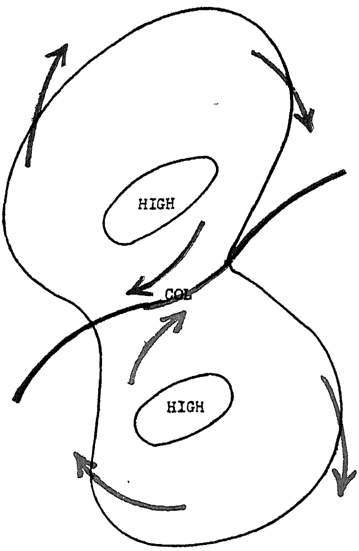


FIGURE 156.

LINE SQUALLS

A line squall is the name given to the phenomenon which occurs with the sudden and complete change of air stream at an unusually well-marked cold front.

With a rapidly rising barometer, violent squalls of cold wind and, probably, heavy showers are experienced.

The phenomenon occurs along a line, usually running in a north–south direction, and is sometimes shown by a long low roll-cloud which appears like a black arch when low down over the horizon.

It is in, or under, this roll-cloud that the violent whirlwinds, called *waterspouts* over the sea or *tornadoes* over the land, may occur.

Figure 157 shows the detailed structure of a line squall.

RECORDING VISUAL OBSERVATIONS

It is necessary to describe briefly the way that weather data are recorded in the deck log and on a synoptic chart when reports are plotted.

Wind. When a ship is not fitted with an anemometer, the direction and force of the wind must be estimated.

Wind direction is specified as that point of the true compass from which the wind blows, and should be observed to the nearest true compass point.

Since the wind direction is seldom constant and may, at times, fluctuate through four to eight points in a few seconds, it is necessary, therefore, to estimate the mean direction. The appearance of the sea and the general run of the waves are good guides. It is almost invariably misleading to base the estimate of wind on an observation of funnel smoke.

DETAILED STRUCTURE OF A LINE SQUALL

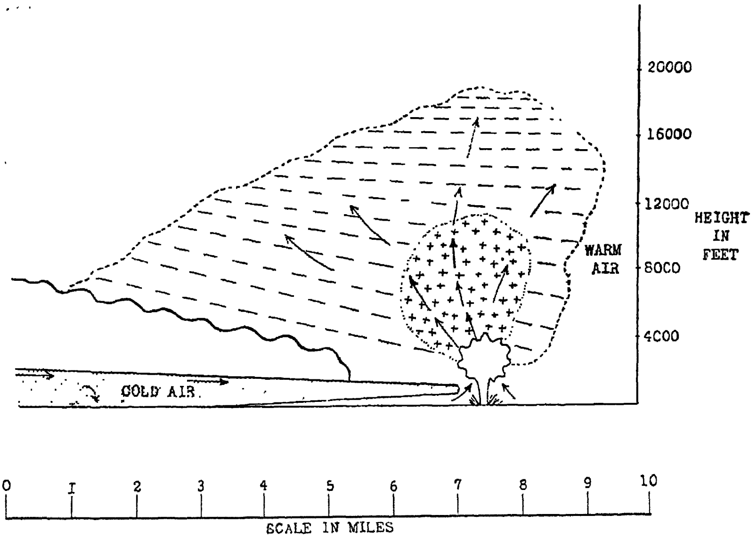


FIGURE 157.

Wind force is expressed by means of the *Beaufort Scale,* a numerical scale devised by Admiral Sir Francis Beaufort in 1808, which has been revised from time to time. This scale is used for logging the wind force in the deck log, for ship's weather reports to shore meteorological authorities and in broadcast synoptic data.

The wind speed corresponding to any Beaufort number according to the table on page 364 is the wind speed at 33 feet above the surface in an open situation.

For the purpose of showing the forces of winds by wind roses on meteorological charts, winds are grouped as follows :

Scale Numbers	
0	calm.
1 to 3	light winds.
4 to 7	moderate winds.
8 and above	gales.

THE BEAUFORT WIND SCALE

Beaufort Number International	METEOROLOGICAL WIND SCALE — Limits of Speeds: Nautical miles per hour	METEOROLOGICAL WIND SCALE — Limits of Speeds: Feet per second	THE SEAMAN'S WIND SCALE — Beaufort's description of Wind International	THE SEAMAN'S WIND SCALE — Deep Sea Criterion (This criterion has not yet been adopted by the International meteorological Organisation.)
	2	*3*	*4*	*5*
	Less than 1	Less than 2	Calm	Sea mirror-smooth.
1	1–3	2–5	Light air	Small wavelets like scales; no foam crests.
2	4–6	6–11	Light breeze	Waves short and more pronounced; crests begin to break; foam has glassy appearance, not as yet white.
3	7–10	12–18	Gentle breeze	
4	11–16	19–27	Moderate breeze	Waves are longer; many white horses.
5	17–21	28–36	Fresh breeze	Waves more pronounced and long; white foam crests everywhere.
6	22–27	37–46	Strong breeze	Larger waves form; white foam crests more extensive.
7	28–33	47–56	Strong wind	Sea heaps up; wind starts to blow the foam in streaks.
8	34–40	57–68	Fresh gale	Height of waves increases visibly; also height of crests; foam is blown in dense streaks.
9	41–47	69–80	Strong gale	
10	48–55	81–93	Whole gale	High waves with long overhanging crests; great foam patches.
11	56–65	94–110	Storm	Waves so high that ships within sight are hidden in the troughs; sea covered with streaky foam; air filled with spray.
12	Above 65	Above 110	Hurricane	

The scale numbers are attributed to the wind force at the time of observation by the observer's judgment. For the purposes of the meteorologist, only winds of force 8 to 10 are gales.

The gale warning signal in the British Isles is hoisted for winds which may reach force 8 or above. For this purpose a wind of force 7 is not considered a gale.

Weather. The state of the weather is recorded in the deck log and on synoptic charts by means of the Beaufort notation. Each phenomenon, with a few exceptions, is indicated by its initial letter, and the complete state of the weather is thus represented by a group of letters.

THE BEAUFORT NOTATION

b blue sky (not more than a quarter of the sky covered).
bc sky partly cloudy (half to three-quarter covered).
c generally cloudy (more than three quarters covered).
d drizzle.
e wet air, without rain falling; a copious deposit of water on trees, buildings or rigging.
f fog.
fe wet fog.
g gloomy.
h hail.
jp precipitation within sight of the ship.
kq line squall.
kz dust storm.
l lightning.
m mist.
o overcast sky.
p passing showers.
q squalls
r rain.
rs sleet, that is, rain and snow together.
s snow.
t thunder.
tl thunderstorm.
u ugly, threatening sky.
v unusual visibility; the horizon or distant hills unusually clear.
w dew.
x hoar frost.
y dry air (less than 60 per cent humidity).
z dust haze; the turbid atmosphere of dry weather.

A capital letter denotes 'intense' or 'heavy', for example:

R indicates heavy rain.

Repetition of a letter denotes 'continuous', for example:

RR indicates continuous heavy rain.

Addition of the suffix 0 to a letter denotes 'slight', for example:

r_0r_0 indicates continuous slight rain.

The letter i placed before a Beaufort letter denotes 'intermittent', for example:

iR indicates intermittent heavy rain.

VISIBILITY. The terms fog, mist and haze are not considered sufficiently precise and, therefore, a visibility scale has been devised, based on the maximum distance at which an object is visible with different degrees of atmospheric obscurity.

This scale is used for making weather reports and plotting synoptic charts.

FOG AND VISIBILITY SCALE FOR SHIPS AT SEA

0	Dense fog.	Objects not visible at 50 yards
1	Thick fog.	,, ,, ,, 1 cable
2	Fog.	,, ,, ,, 2 cables
3	Moderate fog.	,, ,, ,, ½ mile
4	Mist or haze, or very)or visibility.	,, ,, ,, 1 mile
5	Poor visibility.	,, ,, ,, 2 miles
6	Moderate visibility.	,, ,, ,, 5 miles
7	Good visibility.	,, ,, ,, 10 miles
8	Very good visibility.	,, ,, ,, 30 miles
9	Excellent visibility.	Objects visible more than 30 miles

Clouds. Cloud detail is not recorded in the deck log, but in a ship making weather reports or plotting synoptic charts, it is necessary to consider the amount of cloud and the cloud formation at various levels.

Cloud Formation. Figure 148 shows the various forms of cloud and the symbol letters used to denote them. Cloud forms are shown in more detail in the *International Cloud Atlas*.

The *amount of cloud* is denoted by a figure on a scale from 0 to 10. Figure 0 signifies a sky free from cloud. An overcast sky in which no patches of blue sky are visible is denoted by 10.

The code numbers refer solely to the amount of sky covered and not to the density, height or other feature of the cloud.

The amount of low cloud should be separately estimated by imagining that every other visible form of cloud is replaced by blue sky. Ships carrying pilot balloon outfits can find the height of clouds. Full details are given in the *Weather Manual*.

Swell. It is necessary to note carefully the distinction between *sea* and *swell*. Sea is defined as the waves caused by the wind at a place, whereas swell is caused by waves formed by past wind, or wind at a distance.

A short swell means a swell where the length or distance between each successive top of the swell is small.

A long swell means a swell where the length or distance is large.

A low swell means a swell where the height between the lowest and highest part of the swell is small.

A heavy swell means a swell where the height is great.

When weather reports are made, the following scale is used for recording swell :

International Swell Scale

Code Figure		*State of Swell in the Open Sea*
0	None.	Low
1	Short or average length	
2	Long	

Code Figure		*State of Swell in the Open Sea*
3	Short	Moderate height
4	Average length	Moderate height
5	Long	Moderate height
6	Short	Heavy
7	Average length	Heavy
8	Long	Heavy
9	Confused	Heavy

Both sea and swell are recorded in the deck log by means of the *Douglas Sea and Swell Scale,* printed in the preface to the deck log.

The direction of the swell is specified in a similar way to that in which wind direction is specified, that is, the point of the compass from which the swell travels.

International Sea Scale

Scale No.		*Height of waves—crest to trough*
0	Calm	0 feet
1	Smooth	0–½
2	Slight	½–2
3	Moderate	2–5
4	Rough	5–9
5	Very rough	9–15
6	High	15–24
7	Very high	24–36
8	Precipitous	over 36

Times of Observations. Ships making weather reports should, in all parts of the world, use Greenwich mean time. The four principal hours of observation for ships are 0000, 0600, 1200 and 1800 G.M.T.

Observations should be made, recorded and signalled at as many of these hours as possible.

It is most important to be punctual in taking the observations and despatching the messages.

Normally, observations should be completed at the exact hour and the observation of the element which is varying most rapidly should, if possible, be made last, that is, at the exact hour.

Full particulars of the times when land stations make observations are given in the *Admiralty List of Wireless Signals.*

Coding the Ship's Weather Reports. Weather reports from ships are made in the *New International Code* (1929). Full details of this code are given in Volume II of the *Admiralty List of Wireless Signals.*

The necessary code tables for ship reports are also set out on a *code card* (H 353) supplied to all ships that are required to make weather reports.

The messages are made up in groups of five figures, and a special form (H 355) is used.

A specimen ship report is given on the back of the code card. (H 353)

Synoptic Messages. The reporting stations of each country are organized under a central meteorological office to which they forward their observations by W/T, telegraph or telephone. At the central office, the observations are immediately plotted on the current weather map and collected together and broadcast by W/T as a single message, often called a synoptic message.

By picking up such collective messages as may be required, a ship or station can construct a weather map of the area in which it is interested.

Full details about the times of observation, codes, and the information contained in these collective messages are given in the *Admiralty List of Wireless Signals.*

Synoptic Organisation in the British Isles. The headquarters of the British meteorological service is the Meteorological Office, Air Ministry, London. Here the principal work of forecasting weather for the British Isles and adjacent waters is carried on, together with the collection of station and ship reports and their re-issue in three main collective messages beginning at 0705, 1305 and 1805.

Observations are received regularly from H.M. ships in home waters, British ships in the North-Eastern Atlantic and the North Sea, and from 45 land stations in the British Isles.

Messages from these ships and stations are received at the Air Ministry immediately after the observations are taken and the plotting of the current synoptic chart begins forthwith.

The reports are re-issued in three collective messages, beginning at five minutes, thirty minutes and one hour after the time of observation. By international arrangement, the reports from Iceland and the Faroes are included in these transmissions.

Synoptic Organisation in the Northern Hemisphere. Most countries carry out a procedure similar to that in the British Isles. The countries are grouped into regions and send reports to central offices in Paris, Rome, Berlin and Moscow. These offices then transmit summaries to Rugby, and Rugby broadcasts a final collective report to America. The American collective report for Europe is sent from Arlington. These messages, however, go beyond the requirements of the navigator who, in general, will find sufficient information in fleet synoptic messages.

MESSAGES USED IN H.M. SHIPS

Fleet Synoptic Messages. Special messages called fleet synoptic messages are broadcast on the home station and on most foreign stations. They contain reports from ships and from a selection of land stations.

Forecasts of weather in the area to which they apply and details concerning the positions and probable movements of depressions and anticyclones are included when they are known with any certainty.

Full details of these messages are given in the *Admiralty List of Wireless Signals* and the *Weather Manual*.

An example of a fleet synoptic message plotted on form Miscellaneous 58A is shown in figure 158 and described later in this Chapter.

Weather Shipping Messages. The weather shipping message consists of a shortened form of the Home Fleet synoptic message. It contains reports from 12 stations with forecasts for different areas round the British Isles, but it does not include any ship reports. The message is plotted on form Miscellaneous 58A.

Full details are given in the *Admiralty List of Wireless Signals*.

It is most necessary to be familiar with the section concerning W/T weather bulletins in Volume I of the *Admiralty List of Wireless Signals*, because it is often possible to receive a foreign message which will give additional information for an area in which the ship is particularly interested. The reports from Karlsborg and Norddeich, for instance, combined with the weather shipping bulletin give most useful information to ships in the North Sea.

Since all ships transmit their reports within half an hour of the reporting time, it is possible, sometimes, to intercept these messages and plot them before the broadcast is received. Some of the intercepted reports may be exceedingly useful and yet they may not be included in the broadcast.

TO FORECAST THE WEATHER IN A SHIP AT SEA

The following example shows the procedure for making a synoptic chart and weather forecast from a Home Fleet synoptic message.

H.M.S. Dryad, exercising off the Isle of Man on the evening of the 14th August, receives at about 1800 (—1) from Cleethorpes the following 1300 Home Fleet synoptic message :

PART I

Max. 02600 35390 Min. 00004 67148 Min. 00604 56102

PART II

Warm front	58036	57002	Moving N.E.			
Cold front	58036	55033	52063			
Warm front	52063	51107	51130			
Cold front	51130	50128	46156	45177	44200	44244.

PART III

17821	26701	07752
19102	00003	09563
01100	02404	15954
02802	30105	13863
11105	12254	09557
10105	20302	10862
29101	20402	16764
21101	16301	15864
39801	20201	24775
34052	08302	15875

PART IV

60595	41312	08250	04646
60491	25712	28402	16765
60548	19512	02400	14860
60508	18212	29420	12761
60457	09712	18202	15866
60549	20912	02302	15856
60476	16712	30402	13863
60368	33013	32101	26768
60506	16912	28301	11861
60482	28112	00002	19768

Information about Decoding. From the W/T Weather Bulletin section and the off-set page of symbolic forms in Volume I of the *Admiralty List of Wireless Signals*, it is seen that :

1. Part I consists of a statement of the positions of greatest and least pressure, their positions and the direction towards which they are moving in the following code :

Max (or Min) PPPKK, LLlly.

Part II consists of a brief statement, in plain language or in the code indicated below, or in both, amplifying Part I as necessary. When the positions of fronts over the Eastern North Atlantic are known, they are specified by the appropriate key-word (' warm front', ' cold front ', or ' occluded front '), followed by five-figure groups in the form LLlly, giving the positions of selected points on the front referred to.

All the above times are GMT.

Part III consists of reports at 1300 from various land stations and that the form of report is :

IIIAW, DDFww, PPVTT.

Part IV consists of reports at 1200 from various ships and that the form of report is :

YQLLL, lllGG, DDFww, PPVTT.

2. The code used is the New International, extended for Parts I and II as follows:

Symbol	*Meaning*
PPP	Value of maximum or minimum pressure in whole millibars.
KK	Direction, in points, towards which the system indicated by PPP is making.
LL	In Part I Latitude of the centre in whole degrees. In Part II Latitude of a selected point in the front in whole degrees.
ll	In Part I West longitude of the centre in whole degrees (50 added if the longitude is east). In Part II West longitude, in whole degrees of a selected point on the front (50 added if the longitude is east).
y	Unit figures of the sum of the digits LLll, to provide a check.

3. Information concerning where to find details of the observation stations is given in Volume II of the *Admiralty List of Wireless Signals*.

Decoding and Plotting. Plot the message on the form Miscellaneous 58A. In this example the first group of each part is considered in detail.

1. Part I (Positions and movements of greatest and least pressure):

1st Group	..	Max 02600	35390
Code	..	PPPKK	LLlly

Plot the position of the centre of greatest pressure given by LL, latitude 35°N., and ll, longitude 39°W. At this point write the word *high* with the barometric pressure, given by PPP, 1026 mb. below it. Show with an arrow the direction in which the area is moving, as indicated by KK. In this example, the figures 00 indicate that there is no movement and, therefore, the high pressure area is stationary.

2. Part II (Brief statement in plain language amplifying Part I):

1st Group	Warm front 58036	57002 moving N.E.
Code	LLlly	LLlly

Plot the positions of the two places as explained in Part I and show with an arrow the direction of movement.

3. Part III (Land stations) ..

1st Group	..	17821	26701	07752
Code	..	IIIAW	DDFww	PPVTT

Turning to Volume II of the *Admiralty List of Wireless Signals*, proceed in the following order :

(*a*) The first three figures 178 (III) give the name of the station, which is found to be VESTMANNA (Iceland). Should the place not be given on form Miscellaneous 58A, it is necessary to look up the latitude and longitude and plot the position on the chart. The station should be marked with a small circle.

(*b*) Decode the direction (DD) and force (F) of the wind. The direction is given in points from 1 to 32 ; thus a wind due south would be indicated by the figures 16. In this example the figures corresponding to DD are 26. The wind direction is thus W.N.W.

The wind force is given according to the Beaufort scale. In the example the figure corresponding to F is 7. The wind force is thus seven.

(*c*) Plot the wind direction by drawing a short black line, finishing at the station, in the direction from which the wind is blowing.

The wind force is shown by marking off feathers on the low pressure side of the arrow. Each full length feather denotes two steps of the Beaufort Scale, and a short feather one step. The W.N.W. wind force 7 thus appears as shown.

(*d*) Decode the past weather (W)—in this example the figure 1 indicates ‘ variable sky ’—and plot the Beaufort letters bc in *red* ink below and to the right of the station.

(*e*) Decode the present weather (ww). The equivalent figures are 01. These indicate ‘ partly cloudy ’, a state that is shown in the Beaufort notation by the letters *bc*. Plot these letters in *black* ink close to the left of the station unless the code figures are 20–29, or 41–42. If the code figures make one of these numbers, the corresponding Beaufort letters must be plotted below and to the right of the station, clear of the ‘ past weather ’ (W).

(*f*) Plot the barometric pressure in millibars above and to the right of the station, in *black* ink. The letters PP indicate the last two figures of the barometric pressure in millibars. In this example, therefore, the pressure is 1007 mb.

(*g*) Plot the temperature (TT) above and to the left of the station, in *black* ink : in this example 52.

DECODE TABLE.

PRESENT WEATHER
w w
SECOND FIGURE (columns) — FIRST FIGURE (rows)

	0	1	2	3	4	5	6	7	8	9
0	b	bc	c	o	Low Fog	M_o or Z_o	Dust Devil	L	M or Z	jf
1	jp	t	jkz	u	q	Last 3 Hours Heavy Squall	Water Spout	—	—	—
2	/r,d,h, s, rs	/d	/r	/s	/rs	/pr	/ps	/ph(r)	/tlr_o	/TLR
3	kz	kz—	kz	kz+	kzz	ks	k/s_o	k/S	s_o/k	S/k
4	f	/f	/F	f— Sky vis	f—	f Sky vis	f	F Sky vis	F	if
5	d	id_o	d_od_o	id	dd	iD	DD	df	d_or_o,dr	Dr
6	r	ir_o	r_or_o	ir	rr	iR	RR	rf	r_os_o, rs	RS
7	s, rs	is_o	s_os_o	is	ss	iS	SS	sf	sh	Ice Crystals
8	pr	pr_o, pr	PR	ps_o,ps	PS	pr_os_o,prs	PRS	psh	ph(r) $ph_o(r_o)$	PH(R)
9	tlr	r/tlr	S(rs)/tlr	$tlr_o(s_o)$	tlh_o	tlr(s)	tlh	TLR(S)	tlkz	TLH

CODE FIGURE	DAY OF WEEK	OCTANT OF GLOBE.	BAR. TENDENCY	CLOUD	PAST WEATHER	SWELL
	Y	Q	A	C	W	K
0		Lat. N. 0°–90° W.	0	St	b	
1	Sun.	Lat. N. 90°–180° W.	1	Ci	bc	
2	Mon.	Lat. N. 180°–90° E.	3	Ci St	o	
3	Tues.	Lat. N. 90°–0° E.	5	Ci Cu	kz	
4	Wed.		7	A·Cu	f	
5	Thurs.	Lat. S. 0°–90° W.	1	A·St	d	
6	Fri.	Lat. S. 90°–180° W.	3	St Cu	r	
7	Sat.	Lat. S. 180°–90° E.	5	Nb St	s	
8		Lat. S. 90°–0° E.	7	Cu	p	
9				CuNb	tlr	

STATION MODEL

TT C PP
V ww ○ A
(C) W (ww)

The circle denotes the position of the station or ship.
A = Barometer tendency (plotted in RED if Barometer is falling).
C = Form of predominating cloud. Types of low cloud are plotted below the station circle.
PP = Barometric pressure.
TT = Temperature.
V = Visibility (plotted in RED).
ww = Present weather. When ww = 20-29, 41 or 42 it is plotted alongside W.
W = Past weather (plotted in RED).
Feathers of wind direction arrows are to be plotted on the side of the lower pressure.

NOTE. THIS TABLE MAY BE USED WITH FLEET SYNOPTIC MESSAGES WHEN IT IS CONSIDERED UNDESIRABLE TO USE THE MORE COMPLICATED SYMBOLS OF DECODE CARD H.354.

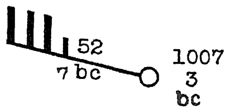
L.2434.

Malby & Sons, Lith.

(*h*) Plot the visibility (V) according to the code number to the left of the 'present weather' (ww), in *red* ink: in this example 7.

(*i*) Decode the barometer tendency (A) which is plotted to the nearest whole millibar, to the right of the station, in *black* ink if the barometer is *rising* and in *red* ink if it is *falling*. In this example the figure 2 indicates a rise of 3 mb. in the last three hours so 3 will be plotted in black ink.

From the above it is seen that the information for Vestmanna is plotted as follows:



NOTE. (i) At any station where there is rain or drizzle, the station circle should be inked in as a black dot. If there is sleet a six-pointed star should be imposed on the dot. If there is snow the six-pointed star should be written alone within the station circle.

(ii) Full information about the arrangement of plotting is given on the decode card H354. The decode card shown facing page 372 can be used with fleet synoptic messages when it is considered undesirable to use the more complicated symbols of decode card H.354.

4. Part IV (Ship reports):

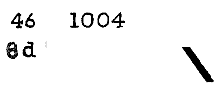
1st Group ..	60595	41312	08250	04646
Code ..	YQLLL	lllGG	DDFww	PPVTT

(*a*) Plot the ship's position. LLL represents the latitude, which in this example is 59°30′ and lll the longitude 41°18′. The letter Q indicates the quarter of the globe. The latitude therefore is north and the longitude is west.

(*b*) Plot the information given in the last two groups in a way similar to that in which land stations are plotted.

(*c*) The letters GG and Y give a check on the time and day when the observations were taken.

The above message would be plotted as follows:



NOTE. The position circle has been inked in, indicating drizzle.

To Draw the Chart. When all the ship and station messages have been plotted, and the positions of the centres of high and low pressure, and the fronts have been shown, the next step is to draw in the isobars and complete the weather chart (*see* figure 158).

Sketch in lightly, in pencil, the even-numbered isobars, shaping them so that the wind arrows are inclined in towards the low pressure side of the isobar, as described earlier in the Chapter.

Where possible—as, for instance, in this example between the positions 57°N., 13°W. and 45°N., 18°W.—show, by means of a sharp bend in the isobars a discontinuity where the isobar crosses a front.

The accurate placing of the limits of pressure on the chart requires practice and experience. If a sequence of weather charts has been drawn from day to day, it will be a simple matter to follow the movement of the various high and low-pressure systems and use this information as a guide for each succeeding chart. It also helps to detect any new disturbance.

In this example there is no previous weather chart and, therefore, the limits of the pressure system must be found by examining the chart.

In addition to the low-pressure systems over Iceland and off the Hebrides and the high-pressure systems over the Azores, it is clear from the map that a well-defined secondary exists off S.W. Iceland. Also the report from the ship in 59°30′N., 41°18′W. shows that there is a low-pressure system over the Western Atlantic. The reports from Gibraltar, Brest and Helder show that pressure is high over France.

From this information it is seen that the isobar of 1016 mb. will not continue to the low-pressure system north of Iceland but will turn to the west round the low-pressure system over the Western Atlantic. Drawn in this way the isobar shows :

1. an even pressure gradient between the Azores and the low-pressure system over the Western Atlantic.

2. the existence of a wedge of high pressure extending north-east from 50°N., 30°W. to 60°N., 22°W.

The continuation of this isobar south-west of Ireland is more difficult, and it is necessary to consider the high-pressure systems near the Azores and over France. The reports from Gibraltar, Brest and Helder make it a simple matter to draw the isobar of 1016 mb. round the high-pressure area over France. The wind direction at Gibraltar indicates that the isobar is probably running approximately east and west, and the wind direction at Brest and Helder indicates that the same isobar will probably be running approximately north-east. This information shows that there is probably a col between these two high-pressure systems.

As for the uncompleted isobar of 1016 mb., south-west of Ireland, clearly it will not continue round the low-pressure system off Ireland by passing through Corunna and Dungeness because the area off the west coast of Spain and Portugal is probably under the influence of a col. It is most likely that the isobar should be drawn round the southern limit of the high-pressure system over the Azores.

The Forecast. From the weather chart it is clear that at 1300 (−1) the ship was mid-way between two depressions which

are moving north-east. She may, therefore, expect to experience the changes of weather associated with the arrival of warm and cold fronts as described earlier in this Chapter.

The forecast as made out at 1800 (—1) will depend on the movement of the approaching secondary depression.

The first indication of this approach will be the cloud formation and rain belt associated with the arrival of a warm front.

If the rain belt has not arrived at 1800 (—1) a suggested forecast is as follows :

H.M.S. *Dryad*. Forecast for 1800 (—1) 14th August.

Pressure is high over France and the Azores, and low over Iceland and the Western Atlantic.

A depression centred north-west of Ireland with an associated secondary south-west of Ireland, is moving N.E.

1. *Period before the Arrival of an Expected Warm Front.* Wind will remain south to south-west, force 3. Barometer steady. Probable continuous rain with good visibility.

2. *Period between the Arrivals of the Expected Warm and Cold Fronts.* A short muggy interval when the sky will be overcast. Poor visibility with the possibility of drizzle. Warmer.

3. *Period after the Arrival of the Cold Front.* With a sharp rise of the barometer there will be a quick veer of wind to north-west, remaining force 3. The sky will clear though a possibility of showers will remain. Visibility good. Cooler.

NOTE. The duration of the periods will depend on the speed of advance of the depression.

STORM SIGNALS

Storm Warnings, more appropriately termed gale warnings, are usually issued when the force of the wind is expected to reach 40 or more knots (force 8 of the Beaufort Scale). The word *gale* is not used to designate winds of less force than 8. According to the Beaufort Scale, a wind of force 10 is classified as a storm.

Most countries transmit gale warnings by W/T in plain language, and in addition display visual gale warnings at coast stations. The details of the W/T gale warnings will be found in the *Admiralty List of Wireless Signals* and the visual gale warnings are given in the appropriate *Sailing Directions*.

British W/T Gale Warnings are broadcast in plain language, and refer to the area which lies within about 150 miles of the station sending out the message. There are 8 stations distributed around the coasts of the British Isles from which these warnings can be transmitted.

Example—' Gale warning. Deep depression off N.W. Ireland moving east. Gales from S.E., backing north, probable north of Lat. 54°. Southerly gales veering N.W. other coasts '.

Gale warnings together with weather forecasts are also broadcast by R/T by the B.B.C. from Droitwich. Information of these warnings is given in the *Admiralty List of Wireless Signals.*

British Visual Gale Warnings. At numerous positions on the coasts of the British Isles gale-warning signals are shown on receipt of instructions from the Meteorological Office, London.

A gale-warning signal indicates that a gale is expected within a distance of 50 to 100 miles of the place where the signal is hoisted.

The gale will usually develop within 10 hours of the time of hoisting the signal. Occasionally, however, it develops more slowly, and the period may be 20 or even 30 hours. The signal will be lowered when the gale has passed, and it is expected that there will be a period of *not less than* 12 *hours* free from gales and high winds, but it is kept hoisted during a temporary abatement of the wind if a renewal of the gale is expected.

The warning signals are as follows:

By day: a black cone, 3 feet high and 3 feet wide at the base.

At night: three lights in the form of a triangle, 4 feet wide at the base. This signal is exhibited at a few stations only.

The north cone (point upwards) is hoisted for gales starting from a northerly point. For gales starting from east or west the north cone is hoisted if the gale is expected to change to a northerly direction.

The south cone (point downwards) is hoisted for gales starting from a southerly point; such gales often veer, sometimes as far as north-west. For gales starting from east or west, the south cone is hoisted if the gale is expected to change to a southerly direction.

Gales sometimes follow each other in quick succession.

Full information concerning the distribution of gale warnings and other meteorological information by wireless telegraphy is given in the *Admiralty List of Wireless Signals.*

Fishery Protection vessels at sea display gale warning signals by day for the areas for which they are responsible. In order to avoid confusion with other authorised signals, a north or south cone is hoisted inferior to the Fishery Flag, the cone having a similar signification to those exhibited at storm-signal stations. No signals are shown at night.

CHAPTER XV

THE OCEAN

OCEAN CURRENTS

An ocean current is a general movement of the water of the ocean which may be permanent or semi-permanent. The term must not be used to denote the tidal streams, which are subject to hourly changes.

The principal cause of ocean currents is the wind. The friction between the moving air and the water over which it passes will set in motion the surface particles, and these particles act on those immediately below them until a general movement of the water is started up and a current established.

The direction, strength and permanence of such a current will depend upon the direction, force and steadiness of the wind. This type of ocean current is known as a *Drift Current,* and its connexion with the wind will be made clear if the current chart facing page 382 is compared with the chart of permanent winds facing page 330.

Ocean currents may also be caused by differences of specific gravity such as result from variations in the temperature and salinity of the water. Differences in salinity arise from :

1. the movement of water from different parts or from different depths of the ocean.
2. loss of water due to evaporation.
3. excess of fresh water due to rain, rivers and melting ice.

These effects, however, are in no way comparable to the effect of the wind.

A drift current is only known as such when it is under the influence of the wind that causes it. Ocean currents not under the influence of the parent wind may be caused by :

1. the momentum of a drift current which carries the water into regions where it is no longer under the influence of the wind that caused the actual drift.
2. the deflection of a drift current by land or shallow water, so that it sweeps on, under its own momentum, in a new direction.
3. the replacement of water, in the form of a counter or compensating current, carried away by the primary current.

Examples of these three types can clearly be seen by comparing the wind and current charts.

The Effect of the Earth's Rotation on the Direction of Drift Currents. The direction of a drift current does not depend entirely on the wind direction. It is also affected by the Earth's rotation. In the *northern hemisphere* the current flows to the *right* of the direction towards which the wind is blowing. In the *southern hemisphere* the current flows to the *left.*

Variability of Currents. Currents are very variable. Even in the main currents which are usually steady in direction, the set may at times be found to be heading towards any point of the compass, and this fact should be remembered when the descriptions of ocean currents which follow are read and current atlases are consulted.

The *Sailing Directions* give details of the seasonal variations of the ocean currents, and *they should always be read in conjunction with the current atlas.*

Current Charts of the World. It can clearly be seen from these charts, which are reproduced facing page 382, that the principal drift currents are caused by the Trade Winds of each ocean, the Westerlies of the Southern Ocean, and the Monsoons of the Indian Ocean. It will also be noticed that the South-East Trade Drifts of each ocean acquire westerly sets on nearing the equator, and become Equatorial Currents. These in turn give rise to Equatorial Counter Currents.

ATLANTIC OCEAN CURRENTS

The S.E. Trade Drift caused by the S.E. Trade Wind, flows to the north-west and eventually merges into the South Equatorial Current.

The Equatorial Current sets to the west across the Atlantic between the parallels of 2°N., and 10°S., and its strength attains to as much as 3 knots. When about 300 miles from Cape Cao Roque, it divides, each part following the coast. One part runs south and forms the Brazil Current, and the other runs to the north-west along the north coast of South America towards the Caribbean Sea, where it joins the N.E. Trade Drift.

The Brazil Current. The portion of the Equatorial Current which turns south along the coast of Brazil, runs as far as the Rio de la Plata, where it turns south-east and east and joins the Southern Ocean Drift.

Inshore of the Brazil Current, the currents run in the same direction as the prevailing wind, which alternates according to the season.

The Equatorial Counter Current. The area of the Doldrums, where there is insufficient wind to set up a drift current, affords a suitable area for the return passage of surface water displaced by the N.E. Trade Drift and Equatorial Current. This counter

current in the Atlantic takes the form of a triangle, from Africa towards Cape Cao Roque, the vertex of which lies in a position that changes with the time of year. In February it is about 25°W., and in August at about 40°W. on a parallel about 5°N.

The Benguela Current. Off the Cape of Good Hope the part of the Aghulhas Current which has entered the South Atlantic is joined by an offshoot of the Southern Ocean Drift forming the Benguela Current. This current sets to the north along the west coast of Africa to the Bight of Biafra where it feeds the South Equatorial Current.

The Gulf Stream. The part of the Equatorial Current which runs to the N.W. and combines with the N.E. Trade Drift consists of relatively warm water. Owing to the shape of the land, it is forced through the West Indies into the Caribbean Sea, at a rate sometimes as high as 3 knots. In this way a large volume of water is heaped up in the Gulf of Mexico, and, since the gulf is shallow and the climate extremely hot, is further heated before it escapes through the only exit open to it—the narrow Straits of Florida, between Florida and Cuba. It reaches the open sea as a belt of excessively salt warm water called the *Gulf Stream*, 50 miles wide and 350 fathoms deep, moving at 4 to 5 knots. It is intensely blue, and its boundaries with the ordinary ocean water are well marked. But for the coral banks round the Bahamas it would go far out to sea. These banks, however, deflect it northward, along the coast of South Carolina. Here it becomes broader and shallower, until at Bermuda it is about 250 miles wide.

On reaching high latitudes it meets the Arctic Current and the banks of Newfoundland and is deflected to the right and acquires an E.N.E. set.

After passing the longitude of the easternmost part of North America the Gulf Stream, as such, ceases to exist, but the prevailing westerly winds continue the easterly set. On approaching Europe the easterly current divides: one branch called the *north-east drift* runs north-east to the Arctic regions: the other branch, called the *south-east drift*, runs to the south and east in the direction of the African coast.

The effect of the south-east drift is to create a clockwise circulation of the surface waters of the North Atlantic along the perimeter of a huge ellipse, the boundaries of which are the eastern and western continents, and the parallels of 20°N. and 40°N. In the central area of the ellipse, where there are no well-marked currents, there is an appreciable quantity of weed called *Sargasso* or *Gulf weed*, on which account the area is known as the *Sargasso Sea*.

Some of the water of the south-east drift current is carried as far as the north-west coast of Africa and then follows the trend of the land from Cape Spartel to Cape Verde, where a large part is

deflected eastward along the Guinea coast. This latter part, which is known as the *Guinea Current*, is joined by the Equatorial Counter Current, and is also augmented at certain seasons by the drift current caused by the prevailing monsoon.

The space separating the Guinea Current from the Equatorial Current is generally about 40 or 50 miles wide. The two currents thus flow side by side in close proximity, but in opposite directions.

The Arctic, Davis Strait or Labrador Current sets down the Davis Strait and flows southward along the coasts of Labrador and Newfoundland to the regions of 41°N. to 42°N. according to the season. Here it meets the Gulf Stream and turns to the east.

The northern boundary of the Gulf Stream, where it meets the Davis Current, is known as the *Cold Wall* and is most marked, both by the colour of the water and the change of temperature of the sea. The Arctic Current, being largely composed of fresh water from melted glacier ice, is green, but the Gulf Stream, being very salt, is blue. The difference in the temperatures of the surface waters may sometimes be as much as 30°F.

In the late spring and summer, when the Davis Strait is no longer frozen over, this Arctic Current brings with it large quantities of ice.

PACIFIC OCEAN CURRENTS

It will be seen from the current charts of the World, shown facing page 382, that the currents of the Pacific differ very little from those of the Atlantic. The principal difference is the periodic change of drift current in the China Sea resulting from the change of direction of the monsoons.

The N.E. and S.W. Monsoon Drifts of the China Sea correspond in strength to the winds that cause them; they generally vary from $\frac{1}{2}$ to 2 knots, but in some localities attain a rate of 4 knots for a short time.

The S.E. Trade Drift of the eastern Pacific flows to the north and north-west until it reaches the parallel of 20°S., where it turns to the west and forms the Equatorial Current.

The Equatorial Current flows westward between the parallels of 5°N. and 10°S. until, on reaching the numerous islands situated between the meridians of 160°E. and 170°E., it divides into two branches: one passes among the islands north of Australia, the other sets to the south-west, skirting the south-east coast of Australia until it meets the general easterly drift of the Southern Ocean. It is then deflected eastward towards New Zealand.

The N.E. Trade Drift flows westward between the parallels of 10°N. and 20°N. until, on reaching the Philippines, it is deflected to the north-east and becomes the Japan Stream.

The Japan Stream or Kuro Siwo (Black Stream) is a warm dark current. It corresponds to the Gulf Stream of the Atlantic, but is

less clearly defined on account of the various islands which it encounters, and is considerably influenced by the prevailing monsoon. It flows along the east coasts of the Philippines and Japan, and then it curves eastward and follows the general easterly drift of the North Pacific. When off Formosa it is about 200 miles wide, and has a maximum speed of 4 knots.

The Oya Siwo is a cold current of pale green water which flows from the Bering Sea along the coast of Khamchatka southward of the Kuril Islands, and then between the coast of Japan and the Kuro Siwo, and finally disappears beneath the warmer and lighter waters from the south.

The Equatorial Counter Current runs eastward between the N.E. Trade Drift and the Equatorial Current, that is, between the parallels of 5°N. and 9°N., until it strikes the coast of Central America.

The Mexico Current is a cold current which corresponds to the Guinea Current of the Atlantic, and is caused in a similar way. It sets down the coasts of the United States and Mexico, and finally merges into the N.E. Trade Drift.

The Peru Current, also known as the **Humboldt Current,** is formed partly by the easterly drift of the Westerlies which results from their deflection by the coast of South America, and partly by the natural formation of a counter current to replace the water displaced by the S.E. Trade Drift and Equatorial Current. It sets to the north along the coast of South America, and finally merges into the Equatorial Current.

INDIAN OCEAN CURRENTS

The currents of this ocean are greatly dependent on the Monsoons.

The S.E. Trade Drift becomes more easterly in direction on reaching the tropic of Capricorn, and gives rise to the Equatorial Current.

The Equatorial Current flows westward between the parallels of 0° or 5°S., according to the monsoon, and 20°S. On reaching Mauritius it divides, one part flowing north and one south of Madagascar.

The part that runs to the north of Madagascar strikes the mainland of Africa at Cape Delgado and again divides: one branch flows northward along the African coast, and the other branch flows southward through the Mozambique Channel, meets the portion of the Equatorial Current which passes south of Madagascar, and with it forms the Agulhas Current.

The Agulhas Current, which is a warm current, skirts the coast of Natal and Cape Colony from 3 to 120 miles from the shore. On reaching the Agulhas Bank it is slightly deflected and skirts the

edge of the shoal, only a small weak portion flowing over the bank. On reaching longitude 20°E. the current is met by the easterly drift from the South Atlantic and is deflected, first southward and then eastward. It finally merges into the easterly drift of the South Indian Ocean.

The N.E. Monsoon Drift, setting south-west, meets the north-going current from Cape Delgado off the African coast in about latitude 2°S. These two currents are then deflected and turn away from the land to the east, thereby forming the Equatorial Counter Current.

The Equatorial Counter Current flows eastward just south of the equator during the period of the N.E. and N.W. Monsoons, between the areas occupied by the N.E. Monsoon Drift and the Equatorial Current. It is assisted in its eastward passage by the N.W. Monsoon, which blows south of the equator.

Currents during the S.W. Monsoon. During this season, the north-going current from Cape Delgado follows the African coast only as far as the parallel of 3°S. It then spreads itself out to the north-east and east and merges into the S.W. Monsoon Drift.

The S.W. Monsoon Drift in the Arabian Sea and Bay of Bengal is deflected on striking the west coasts of India and Burma, and south-east currents flow along these coasts.

Currents in the Red Sea. The general set is to the south except during the N.E. Monsoon. The N.E. Monsoon drift is then forced into the Gulf of Aden and causes a northerly set in the southern part of the Red Sea.

MEDITERRANEAN SEA CURRENTS

The currents of this sea are generally weak and variable.

A General Easterly Set is found in the Strait of Gibraltar, the western basin, and along the north coast of Africa. From Gibraltar, as far east as Cape de Gata, this easterly current runs with greater velocity than in other parts of the Mediterranean, often attaining a rate of over 3 knots. Off the African coast, the easterly current is stronger within 20 miles of the shore than it is further out. It is thus advisable for west-bound ships to keep further from the shore than east bound.

A General Westerly Set following the curves of the land is found along the northern shore of the Mediterranean.

WAVES

The following are definitions of terms frequently used in connexion with waves.

The Length of a Wave is the horizontal distance (usually expressed in feet) from crest to crest or trough to trough.

The Height of a Wave is the vertical distance (usually expressed in feet) from trough to crest.

The Period of a Wave is the time, in seconds, between the passage of two succeeding wave crests or troughs past a *fixed* point.

The Velocity of a Wave is the rate at which its crest travels and is obtained by dividing the length by the period, the result being the velocity in feet per second.

Sea and Swell. Waves that are set up by wind blowing at the place and time of observations are termed *sea.*

Waves caused either by wind at a distance from the place of observation or by winds in the locality previous to the time of observation are termed *swell.*

Ocean waves result from the friction of the wind on the surface of the water. When first formed they are short and steep, but if the wind continues to blow in the same direction for a considerable time, their *length* and their *height* increases. At the same time, the *period* of the waves increases until a balance of forces is reached. When waves have been formed, the wind has its greatest effect on their crests, which it tends to drive faster than the main body of the waves. It thus causes the waves to break. In deep water, waves have no motion of translation, but, on reaching shallow water, their troughs are retarded, with the result that the waves themselves rush forward and break with considerable violence. From this action they are known as *breakers.*

The Dimensions of Waves vary in different localities and with different velocities and directions of the wind. The longest waves are encountered in the South Pacific, where their lengths vary from 600 to 1,000 feet, and their periods from 11 to 14 seconds. Waves of from 500 to 600 feet in length are occasionally met with in the Atlantic, but more commonly the lengths are from 160 to 320 feet and the periods from 6 to 8 seconds. The longest wave recorded was 2,600 feet and had a period of 25 seconds. The relation between the length of a wave and the velocity and direction of the wind is not yet fully understood.

The procedure for determining the length and period of waves will be found in Volume III.

SPECIFIC GRAVITY OF SEA WATER

Specific Gravity and Colour of Sea Water. The specific gravity of sea water is found to vary between 1·021 and 1·028 according to its temperature and to the percentage of salt contained in it.

In the tropics the amount of salt contained in the surface-water is above the average on account of the excessive evaporation which takes place in low latitudes; on the other hand, in high latitudes the amount of salt is below the average on account of the large amount of fresh water from melted ice which mixes with it.

On the average, 77·8% of the solids contained in sea water consist of common salt. The following table shows the average percentage of salt contained in sea water in different parts of the world:

Atlantic Ocean	3·6
Caribbean Sea	3·6
Mediterranean Sea	3·8
Red Sea	4·1
Indian Ocean	3·6

Near large rivers, the fresh water running seaward lowers the specific gravity for a considerable distance. The effect of fresh water of the Rio de la Plata, for example, has been detected at a distance of 1,000 miles from the mouth of the river.

It has been found that there is a distinct relation between the colour of sea water and the percentage of salt contained in it: the more salt that is held in solution, the bluer the water, and the less salt, the greener the water. In landlocked seas such as the Mediterranean and Red Seas, where the evaporation is great and where there is little circulation of the water with that of the neighbouring oceans, the colour of the water is very blue. This depth of blue also marks the surface water of currents such as the Gulf Stream, which come from the tropical regions. The currents which come from polar regions, such as the Davis Strait Current, are distinctly green.

Off the estuaries of large rivers, the sea water is often discoloured for a great distance by the sediment brought down by the rivers.

Currents through Straits Connecting Seas of Different Specific Gravity. When a strait connects two seas of different specific gravities, the surface current flows into the sea with the higher specific gravity, while the bottom current flows in the opposite direction.

This state of affairs occurs in the straits forming the entrances to the Mediterranean Sea. The surface currents flow through the Strait of Gibraltar and the Dardanelles into the Mediterranean, while the bottom currents flow from the Mediterranean into the Atlantic Ocean and Sea of Marmora. In these straits, the surface currents are stronger than the bottom currents, because the greater evaporation from the Mediterranean tends to lower its relative surface level. This causes more water to flow in than out.

TEMPERATURE OF THE SEA

The Surface Temperature of the Sea varies considerably in different parts of the world, and chiefly depends on the temperature of the prevailing currents. Owing to the low conductivity of water, a warm current communicates only a little of its heat to the water through which it passes.

The temperature of the sea varies through the year, but the

diurnal variation is very small, the temperature being practically the same by night as by day.

In the tropics the average temperature of the sea is about 80°F., the highest readings of about 90°F. being found in the Red Sea. The lowest temperature of the sea is found in the polar regions. The temperature at which sea water freezes is about 28°F. In freezing, crystals are formed that are free of salt, but intermingled with these crystals in the ice there is brine.

The normal temperatures of the various oceans are shown on charts supplied to H.M. ships, and on them all points at which the temperatures are the same are joined by isotherms.

Thermometer for Sea Temperature. One of the ordinary A.M.O. thermometers, similar to those in a psychrometer, should be used for taking the surface temperature of the sea for entry in the ship's log. This is done every four hours. A metal case is supplied to enclose the thermometer and prevent it from breaking. The water should be drawn clear of any discharge from the ship—the nearer the bow the better—and the thermometer immersed for several minutes. If a canvas bag is used, it should not be placed in a draught, because evaporation will materially lower the temperature.

ICE

The sea is completely frozen during the winter months in high latitudes, except in places where its temperature is raised by warm currents. The Atlantic coast of North America is fringed by ice to a latitude considerably south of that of the English Channel, whereas on the west coast of Europe the sea does not freeze because there is no cold Arctic Current, the passage of which has been barred by the Gulf Stream and subsequent easterly set.

Definitions of the various types of ice formation met in the polar regions are given in the *Weather Manual* and also in the appropriate *Sailing Directions*. These types may be divided into two main groups :

Ice which Prevents Navigation. This includes Field Ice, Floe Ice, Pack Ice, Hummocky Ice and Bay Ice.

Ice through which Ships can Pass. Drift Ice, Brash Ice, Sludge Ice and Pancake Ice.

In the spring and summer, the icefields of the polar regions are, to a great extent, broken up. Ice in various forms is then carried by wind and current into the temperate zones, where it becomes a menace to shipping.

Icebergs are generally white, but are of two distinct types.

1. Those formed or calved from glaciers.
2. Those formed or calved from ice barriers.

1. **Icebergs Calved from Glaciers** are generally masses of frozen and compressed snow with irregular tops.

This type is common in the western part of the North Atlantic. They are generally calved from the glaciers of Greenland, and are sometimes carried by the Arctic Current as far south as latitude 39°N.

2. **Icebergs Calved from Ice Barriers** are flat topped and are often much larger than those formed from glaciers. Most Antarctic icebergs, being calved from the Great Ice Barrier, are of this type, and sometimes resemble floating islands. Ice islands up to 70 miles in length have been seen in as low a latitude as 55°S. in the region near South Georgia.

Size of Icebergs. In either hemisphere, an iceberg rising 300 feet above the sea-level is rare, although bergs of 1,000 feet in height and 20 miles in diameter have occasionally been observed.

The size of icebergs is often deceptive. No glacier berg has been known to exceed 450 feet above the sea surface after calving, and in the region of the trade routes in the western part of the North Atlantic those measured do not exceed 270 feet above the sea, or 1,700 feet in length along the waterline.

Proportion of an Iceberg Submerged. This varies according to the amount of air trapped and the weight of earth and stones frozen into its base when the iceberg is formed. Icebergs calved from glaciers are more solid and contain more earth and stones than those calved from ice barriers.

A solid berg may be submerged to nearly seven-eighths of its whole volume so that an iceberg 300 feet high may draw about 350 fathoms of water. [The probable reason of the absence of icebergs in the North Pacific Ocean is the shallowness of the Bering Sea.]

When icebergs, the bases of which contain much earth and rubble, become reduced in volume by melting, they cease to be buoyant after a certain point is reached and founder.

In the huge bergs calved from the Great Ice Barrier of the Antarctic, the air spaces are so great that, as a general rule, not more than three-quarters of the berg is submerged.

Floebergs are thick pieces of salt-water ice which resemble small icebergs.

Growlers are small bergs, dark blue instead of the usual white.

INDICATIONS OF THE PROXIMITY OF ICE

A good look out is the most dependable method of detecting the presence of ice.

The proximity of ice may be indicated by the following signs, and should any of them be observed, caution is necessary:

1. *Ice blink.* This is a yellowish white light reflected from snow-covered ice on to the sky near the horizon in clear weather, and it is seen in the direction of the ice before the ice itself is visible.

Ice blink indicates pack ice. Only on rare occasions does it result from icebergs.

2. The absence of a *sea* in a fresh breeze. This is a sign that there is land or ice on the weather side.

3. The appearance of herds of seal or flocks of birds far from land.

4. The ice cracking, and pieces of ice falling into the sea. These make a noise like breakers or the far-away discharge of guns, and may often be heard from a considerable distance.

NOTE. (*a*) The presence of an iceberg has no appreciable effect on the temperature of the air or of the sea in its vicinity, and therefore the thermometer cannot be relied upon to give warning of ice, but since the ice-bearing currents from the polar regions are cold, there is a likelihood of seeing ice when the sea temperature and the set and drift of the current indicate that a ship is in one of these ice-bearing currents.

(*b*) Echoes of sound reflected from icebergs are uncertain so that warning by echo of the steam whistle or siren is quite unreliable.

NAVIGATION IN THE VICINITY OF ICE

Keep a good lookout and remember that :

By Day.

1. fog occurs frequently in the regions of drifting ice.
2. in light fog or drizzle an iceberg may be visible from 1 to 3 miles, and it may be assumed that a lookout aloft will sight an iceberg before it is sighted on deck.
3. in dense fog an iceberg cannot be seen more than 100 yards ahead of the ship, and a lookout on deck will probably sight the sea breaking on the base of the iceberg or the growlers and fragments of ice detached from it, before it is visible from aloft.
4. in dense fog it is advisable to stop the ship and wait for the fog to lift.

By Night.

1. on clear dark nights bergs sometimes become surrounded by a faint mist which makes it very difficult to see them, and even in the absence of this mist they will not be visible with the naked eye for more than a quarter of a mile.
2. on clear moonlight nights, according to the relative positions of the Moon, the berg and the ship, an iceberg may be seen at distances up to eight miles.

Avoiding Action. If an iceberg is sighted right ahead in low visibility, the safest avoiding action is to proceed full speed astern with the wheel amidships. If the wheel is put over in an endeavour to avoid the iceberg, the side of the ship is exposed to the submerged ledges.

Icebergs, floebergs and growlers should not be passed close to because it is possible that there are projecting ledges below water,

and there may be smaller masses of drift ice in the vicinity of the bergs. No definite rule can be laid down about passing to windward or to leeward of icebergs. Their out-of-water size suggests that they drift faster to leeward than the hard, small invisible pieces which are often found near them; but an iceberg is frequently found setting to windward owing to a strong undercurrent.

North Atlantic International Ice Patrol. Each year the International Ice Observation and Ice Patrol Service begins its patrol in March and continues during April, May and June, and longer if necessary. Two United States coastguard cutters working alternately carry out the patrol.

The object of the service is to locate icebergs, and field ice near to the North Atlantic Lane Routes in the vicinity of the Great Banks, so that W/T ice warnings may be sent out daily. The procedure for sending these messages is given in *The Admiralty List of Wireless Signals.*

Ice Charts. The average limits within which ice may be expected are given in the appropriate *Sailing Directions*, but by far the most valuable information is given on an ice chart, compiled from the latest reports published in *The Marine Observer*, which is a quarterly review with monthly supplements published by the Meteorological Office.

The following ice charts are published by the Hydrographic Department:

5031—5042—Atlas containing twelve sheets, one for each month, for the northern hemisphere (1922).

1241 —Ice chart of the southern hemisphere (1931).

These charts are periodically revised from information received from the Marine Division, Meteorological Office.

North Atlantic Lane Routes. As the limits of the area in which ice is liable to be met with vary at different times of the year, the best tracks to follow across the North Atlantic are given on the North Atlantic route chart, in *Ocean Passages for the World*, and in the appropriate *Sailing Directions*, all of which are published by the Hydrographic Department and supplied to H.M. ships.

Occasionally the ice extends over larger areas than usual, and when this occurs the tracks are temporarily modified, notice of the alteration being given in *Notices to Mariners.*

APPENDIX I

THE SEXTANT AND THE BUBBLE SEXTANT

Principle. The sextant is so called because the graduated arc is about one-sixth of a circle.

The principle on which the sextant is built is that if a ray of light is reflected twice in the same plane by two plane mirrors, the angle between the first and the last directions of the ray is twice the angle between the mirrors. The proof of this principle is given in Volume II. For this reason the arc of the sextant is graduated up to 120°.

Description of the Sextant.

The sextant, shown in figure 161, consists of :

1. a metal frame A, one edge of which is a circular arc CD.
2. an arm B, called the index bar, which can rotate about the centre of the arc.
3. a small frame I, mounted on the index bar over the centre of the arc, which carries a mirror called the index glass.
4. a small frame H, perpendicular to the frame A, in which is fitted a glass mirror called the horizon glass, the left-hand half of which is unsilvered.

The arc CD is graduated in degrees, each degree being divided into six divisions of 10′, and so arranged that, when the index glass is parallel to the horizon glass, an index on the index bar should point to the zero, 0, of the scale. The graduations are continued over a small arc on the other side of 0, which is called the arc of excess. The index bar can be secured in any position on the arc CD by means of a clamping screw beneath it, and, when clamped, it can be given a slow motion to one side or the other by means of a screw E, called the tangent screw. The setting of the index on the scale can be read accurately by means of a vernier, the principle of which will be explained later. A small microscope F, carried on an arm pivoted on the index bar, is fitted to simplify the reading of the graduations.

The telescope G is carried in a collar J, which can be raised or lowered by a milled head K beneath the frame. In the normal position of the telescope equal parts of the silvered and unsilvered halves of the horizon glass should be visible. The action of raising or lowering the telescope regulates the brilliance of the reflected image, which will be greatest when the telescope is screwed hard down. As the telescope is raised, less of the silvered part of the

horizon mirror appears in the field and the reflected image is less bright.

This action is most useful when it is necessary to regulate the relative brilliance of the horizon and the reflected heavenly body. The telescope is so arranged that its axis makes the same angle with the plane of the horizon glass as the latter makes with the line joining the centres of the index and horizon glasses. Two sets of coloured shades, L and M, are fitted for use when observations of bright objects are taken. On the opposite side of the frame to that shown in figure 161 are three legs and a wooden handle N.

NOTE. Sextant mirrors have, in the past, deteriorated from unavoidable exposure to sea-spray. This has been overcome in the latest types of sextant by fitting hermetically sealed mirrors. To obtain efficient sealing, the mirrors have to be made circular, as shown in figure 162.

The Sextant Telescopes. A sextant is generally provided with two telescopes and a plain tube. The latter, which has no lenses, is provided to ensure that the line of sight is parallel to the plane of the instrument.

The principal telescope is called the inverting telescope, because, on account of the arrangement of the lenses, objects seen through it appear to be inverted. It has two eye-pieces, one of which is of higher magnifying power than the other ; and each is fitted with cross-wires at its focus to define the line of collimation, which is the line joining the focus to the centre of the object-glass. The eye-piece of higher power generally has two cross wires and the lower-power eye-piece has four.

The high-power eye-piece should be used when the horizon is bright and the ship is steady.

In addition to the inverting telescope, there is usually a star telescope, which is bell-shaped and has a large object-glass. It is an erecting telescope, and since it is intended for taking observations of stars, its magnifying power is not high.

The purpose of the large object-glass is to overcome the restriction of the field of view which results from the erecting eye-piece, and to give increased illumination. The star telescope is also of considerable value when angles between two terrestrial objects are measured, and it should always be used when such observations are made.

There are, on the market, various sextant attachments of which the following are examples :

Power 6 Prism Star Monocle.
Double Star Prism, for use with cloudy horizons.
Astigmatiser, for elongating the image of a star.

The Vernier. The principle of the vernier is described in Volume II. The vernier itself consists of a scale which slides along the sextant arc and permits the sextant arc to be read with an accuracy greater than that obtained by a direct reading.

[To face p. 390.

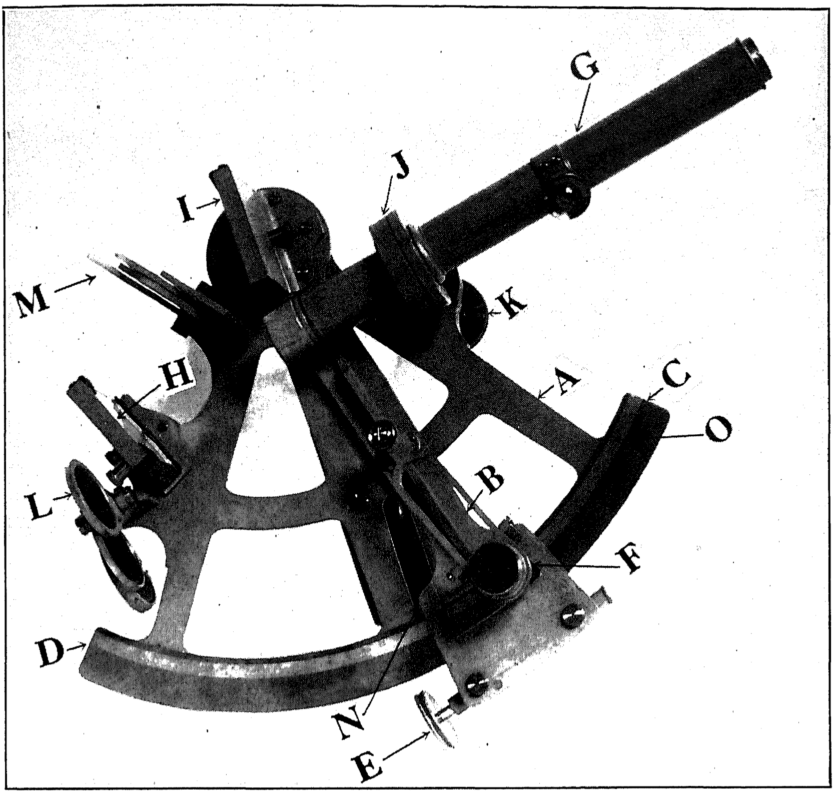


FIGURE 161.

To face p. 391.]

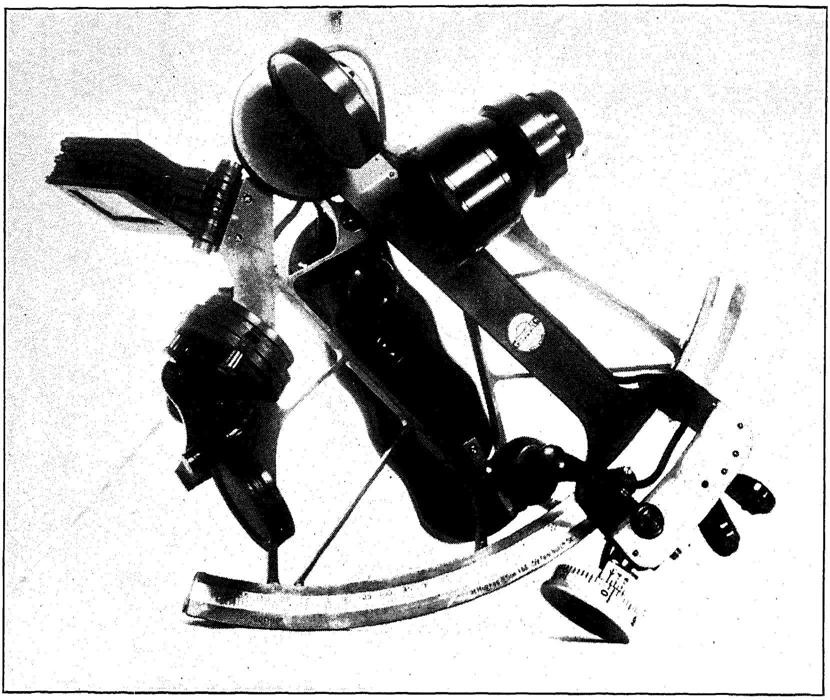


FIGURE 162.

On the arc of the sextant each degree is divided into six divisions of 10′.

On Admiralty sextants the arc of the vernier is divided into ten major divisions, each representing one minute of arc, and each of these major divisions is subdivided into five smaller divisions, each therefore representing 12 seconds of arc. Thus the vernier enabels the arc to be read to the nearest 0·2 of a minute.

The verniers of most sextants not built to Admiralty specifications are graduated to read to 10 seconds of arc.

When angles *off the arc* are read, the 1′ and 12″ intervals *must* be counted from the *left-hand* end of the vernier.

In place of a vernier, modern sextants are fitted with a micrometer screw with a head about an inch in diameter on which the readings are marked in black on a white ground, as shown in figure 162. This is a great advantage because readings are clear and easily discernible in poor daylight or in dim artificial light.

The micrometer is an expensive fitting, and at the present time it is unlikely that a cheap model will prove reliable.

Errors of the Sextant. There are two types of errors of the sextant.

1. Adjustable errors which can be detected and eliminated by the observer.
2. Certain other errors which can be corrected only in a workshop.

Perpendicularity. The index glass must be perpendicular to the plane of the instrument. Set the index bar near the middle of the arc. Hold the instrument horizontally, and look obliquely into the index glass. The reflected image of the arc should now be seen in line with the arc itself. Should the two not appear in line, they can be made to do so by rotating a small screw in the centre of the frame of the index glass.

This error must always be corrected first.

Side Error. The horizon glass must be perpendicular to the plane of the instrument. Ship the inverting telescope and, with the sextant vertical, look at some well-defined distant object, preferably a star, and move the index across the zero of the arc. The reflected image should pass over the direct image of the star. If it does not do so, the error can be taken out by a screw in the centre of the frame of the horizon glass.

Collimation Error. The axis of the telescope when shipped should be parallel to the plane of the instrument. First take out perpendicularity error and side error and ship the inverting telescope with the wires parallel to the plane of the instrument. Choose two heavenly bodies not less than 90° apart, and bring them into accurate contact on one wire of the telescope. Move the sextant

until the bodies are on the other wire. They should still be in contact. If not, there is collimation error. This can be corrected in some sextants by two screws on the collar.

Index Error. The horizon glass should be parallel to the index glass when the index is at zero. Index error can be found in several ways.

1. *By observing the diameter of the Sun ' on ' and ' off ' the arc.*

Set the sextant approximately at zero and work the tangent screw to make the two images of the Sun just touch each other. Note the reading ' on ' the arc. Then reverse the images and note

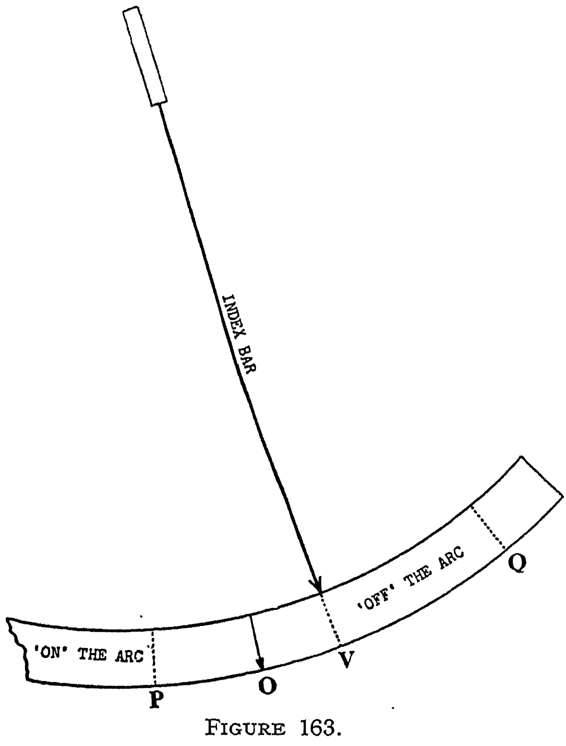


FIGURE 163.

the reading ' off ' the arc. Half the difference of these readings is the index error, which is positive (+) if the greater reading is ' off ' the arc, and negative (—) if the greater reading is ' on ' the arc. This can be seen clearly in figure 163 where:

O is the zero graduated on the arc
P is the position of the index when the Suns are touching ' on ' the arc.
Q is the position of the index when the Suns are touching ' off ' the arc.
V is the point at which the arc should be graduated zero.

When the index is at P 'on' the arc, the reflected Sun, which is shaded, is below the direct Sun, which is not shaded. When the index is at Q, 'off' the arc, the positions are reversed, as shown in figure 164.

In each of these observations, the angle measured is that subtended by the Sun's diameter, since the upper limb of one image is made to touch the lower limb of the other.

OP and OQ are the sextant readings when the observations are made, and clearly they differ by twice OV, the index error. The index error is thus half the difference between two sextant readings of the Sun's diameter.

The sextant readings 'on' and 'off' the arc added together and divided by four, should be the semi-diameter of the Sun given in the *Nautical Almanac* for the day, and this affords a check upon the accuracy of the observations.

2. *By observing a star.* Set the index bar a few minutes one side or other of zero; then observe a star and bring the two images together so that one is indistinguishable from the other. The reading is the index error, minus (—) if 'on' the arc, and plus (+) if 'off' the arc.

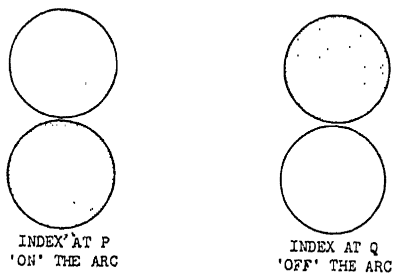


FIGURE 164.

It can be seen in figure 163 that if the index is at V when the images coincide, OV is the index error 'off' the arc and therefore plus (+).

3. *By observing the horizon.* Index error can be found by observing the horizon in a similar way to finding the error by observing a star. This method should not be used unless there is no heavenly body available.

Notes on Index Error. It is not a good policy to correct small index errors (under 3′) since there is always a danger of straining the horizon glass and making the adjusting screw slack. A small index error should be allowed for arithmetically in the working of the sight.

If the index error becomes large and unwieldy (over 3′) it should be corrected by the small screw at the side of the base of the horizon glass. If this adjustment is made, side error should also be checked.

When the index error is corrected, it is a good plan to ensure that any index error remaining is positive (+), because this simplifies the working of sights and avoids errors of subtraction.

ERRORS WHICH CANNOT BE CORRECTED BY THE OBSERVER

Centering Error exists when the pivot of the index glass is not at the centre of the arc. The error varies with the angle measured.

Prismatic Error occurs when the mirrors are not plane.

Shade Error occurs when the shades are not plane.

At the National Physical Laboratory, the centering error and all residual errors are observed and tabulated for various angles, and entered on the certificate in the lid of the sextant box.

An 'A' certificate means that the errors do not exceed 40″, tabulated for every 15° of the arc.

A 'B' certificate that the errors do not exceed 2′, tabulated for every 30° of the arc.

No certificate is granted if the errors exceed 2′.

BUBBLE SEXTANTS

Advantages

1. Observations of the Moon and stars can be taken throughout the night.
2. Observations of heavenly bodies can be taken by day when there is no visible horizon.

Disadvantages

1. There is an error caused, which at present cannot be overcome, by bubble acceleration caused by the ship's movement.
2. For the above reason reliable results cannot be expected from observations taken in a lively ship in a seaway.

Types of Bubble Sextants. There are two types of bubble sextants.

1. Sextants designed solely for use with the bubble. This type is used primarily for air navigation, but the *Modified Mark VIII* sextant, shown in figure 165, is being developed for use in H.M. ships.
2. Sextants with a detachable bubble horizon. The *Gothic* sextant (with detachable bubble horizon) shown in figure 166, is an example of this type.

THE CARE OF A SEXTANT

1. Always handle a sextant with great care. A slight blow is liable to derange the adjustments.
2. When lifting, always hold the instrument by the frame or handle and never by the arc or by the index bar.
3. When screwing a telescope into the collar, take care not to burr the threads.

[To face p. 394.

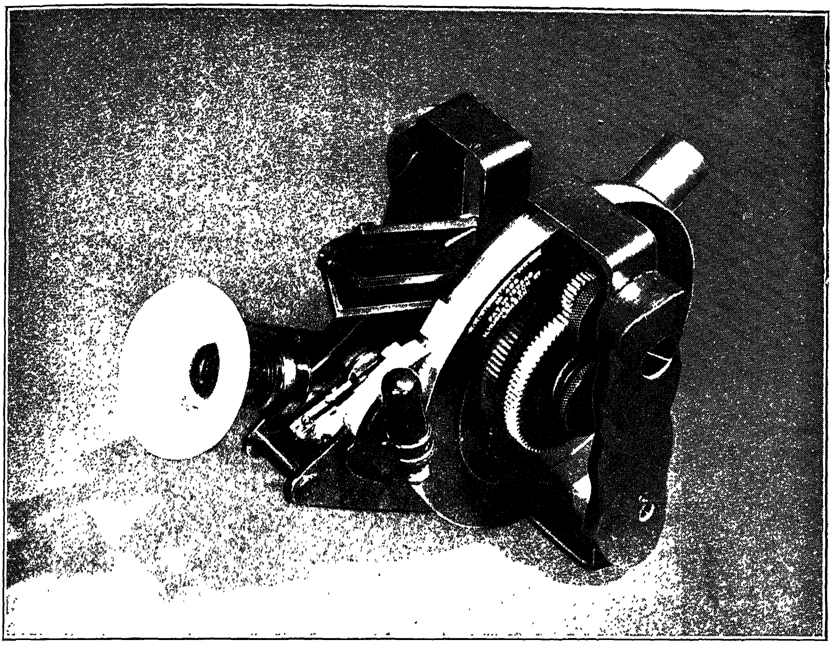


FIGURE 165.

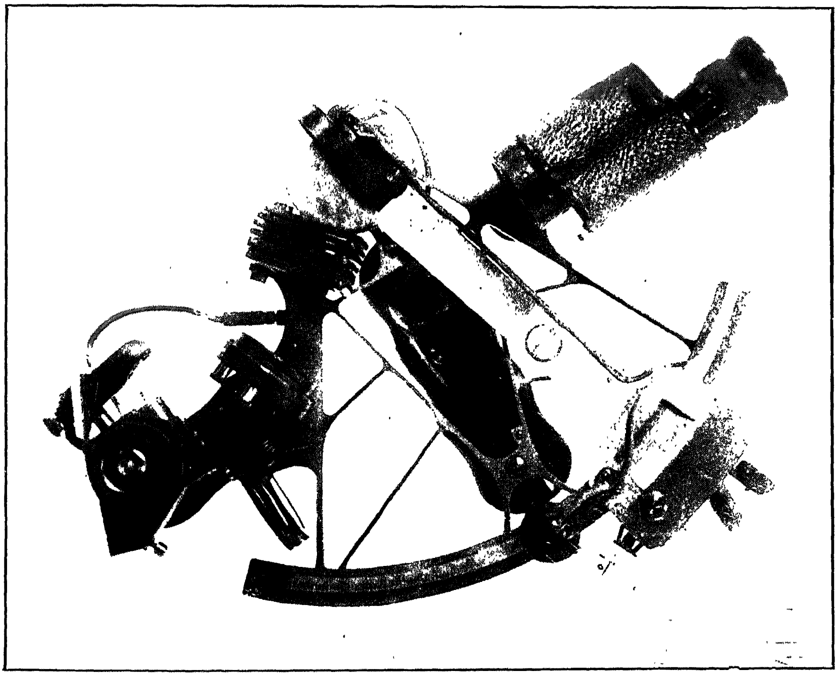


FIGURE 166.

4. If the graduations are difficult to read, the arc should be smeared with clock oil mixed with lamp-black and then lightly wiped. This cleans the arc in addition to making the graduations stand out.

5. Never leave the sextant exposed to the Sun's rays.

6. After using the sextant in damp weather or when there is spray, wipe away all trace of moisture, using a chamois leather or a clean silk handkerchief and paying particular attention to the arc and mirrors.

7. Always stow the sextant in a place where it is not liable to be moved. If possible the stowage should be free from vibration and damp.

8. If the sextant is being stowed away for a long period, a thin coat of vaseline preserves the arc.

NOTES ON THE SEXTANT

1. It is a good plan to mark the various eye-pieces so they can be readily set to the correct focus, and thus avoid making an adjustment every time the instrument is used.

2. If the sextant is not fitted with an endless tangent, the tangent screw should be kept nearly in the middle of its run when not in use.

3. Always test the sextant for perpendicularity, side error and index error before taking sights. The first two should be taken out. If the index error is under 3′, it is advisable to leave it in and allow for it arithmetically.

4. When angles are measured with a sextant, it is important that the objects should be observed in the centre of the field of the telescope, in order that the ray from each of the objects may be parallel to the plane of the instrument.

5. When measuring very small angles such as vertical danger angles, or the angles measured when the index error is checked by the Sun, read both ' on ' and ' off ' the arc.

6. When reading the sextant, avoid holding it sideways to the light, but let the light come straight along the index-bar to the vernier.

7. It is preferable to use a dark glass at the eye end of the telescope instead of using the shades.

8. The glasses are apt to get coated with moisture, especially after sunset.

9. If working with a new sextant, or if out of practice, take sights with the ship at anchor in a known position, and so determine any personal error.

APPENDIX II

NOTES ON SIGHTS

A single observation of a heavenly body or a terrestrial object gives a position line.

The Use of a Single Position Line. Although it is not possible to obtain the ship's position from a single position line, the line itself can be of great use when the ship is near land.

Suppose that, in figure 167, a ship wishes to pass 10 miles from the lighthouse and proceed up a channel in thick weather, and that

THE USE OF A SINGLE POSITION LINE

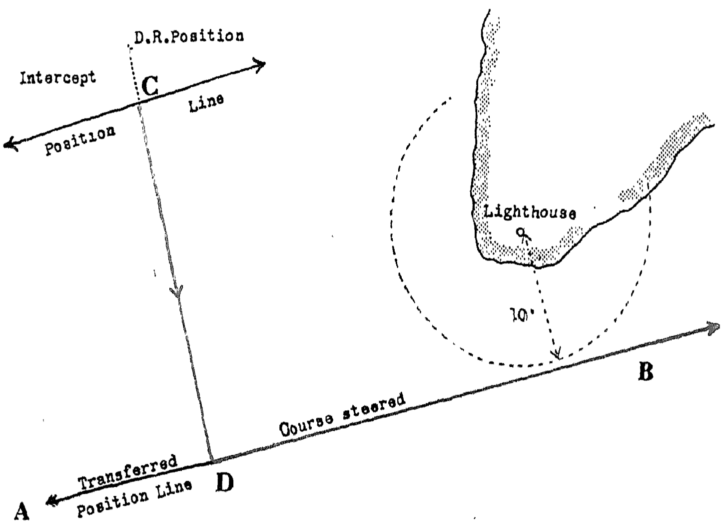


FIGURE 167.

an astronomical observation gave the position line shown before the weather became thick.

If the line AB is drawn tangential to the 10-mile circle, parallel to the position line, and the ship steams the distance CD and then alters course along AB, she should, if there is no unknown tidal stream or current, pass 10 miles clear of the lighthouse.

The Fix and the Observed Position. One position line combined with another gives the ship's position. If the two position lines are obtained from shore objects, her position is called a *fix*. If they are obtained from heavenly bodies, it is called an 'observed

position'. The distinction is made because a position obtained from astronomical observations is not so reliable as one obtained from terrestrial bearings.

The Transferred Position Line. If two position lines are obtained at approximately the same moment, the ship's position is decided by their point of intersection. If there is an appreciable interval between the times at which they are obtained, the first position line must be ' run on ' to allow for the distance that the ship covers in that interval. The ship's position at the time of the second position line is then decided by the intersection of the second position line and the first position line transferred.

Too much reliance must not be placed upon a position found by the transference of a position line if :

1. there is a long interval between sights, because the run is never accurately known, especially in tidal waters.
2. the angle of cut between the two position lines is less than 30°, because even small errors in the altitude considerably affect the position found.

Heavenly Bodies suitable for Observation. In daylight it is sometimes possible to obtain simultaneous observations of the Sun and the Moon, or the Sun and Venus, or Venus and the Moon, and so avoid any run between sights. The best observations, however, are obtained of the Moon, planets and stars at *morning and evening twilight.*

The most reliable observed position is obtained if the bearings of the two heavenly bodies differ by about 90°.

Meridian Altitude Sights. It is more satisfactory to work out the time of meridian altitude beforehand and to take observations at that time, than to wait for the Sun to dip, even if this is possible.

Limiting Altitudes for Astronomical Observations. When the altitude of a heavenly body is low, the effect of refraction is uncertain and may be large. Sights of heavenly bodies, the altitudes of which are less than 10°, should therefore be avoided unless there are no other heavenly bodies available. In that event, the results must be used with caution. Also, when the altitude of a heavenly body is over 80°, its accurate measurement is difficult. For these reasons, it is advisable, if possible, to take observations of heavenly bodies, the altitudes of which lie between 10° and 80°.

Abnormal Refraction. Positions obtained from sights taken during the day can be dangerously misleading owing to abnormal refraction. Mirage effects indicate that the refraction is abnormal, and any unusual difference between the sea-surface and air temperatures indicates that it may be. In the Red Sea, for example, abnormal refraction is a common experience because the wind which blows off the land is heated to a temperature considerably higher than that of the sea.

If abnormal refraction is suspected, sights should be treated with the utmost caution.

Star sights at morning and evening twilight are more likely to give accurate results than observations taken at other times.

Identification of Stars and Planets. This can be done by means of star charts (examples of which are given in Volume II) and the star globe.

The *star globe* is a small globe revolving in a brass ring which is graduated in degrees and represents the meridian. Globe and ring fit into a hemispherical hollow in a box, the edge of which is graduated in degrees and represents the horizon. Over the globe is fitted a hemispherical cage which consists of two semicircles at right-angles to each other. These semicircles are graduated in degrees and represent circles of altitude.

To use the star globe, set the meridian ring to the latitude. This is most easily done by making the elevation of the pole equal to the latitude. Then revolve the globe in the ring until the time equal to the right ascension of the meridian appears under the meridian ring. Next revolve the brass cage until one of the semicircles points to the observed true bearing of the body, and move the small pointer up the circle of altitude to the observed altitude; the pointer now indicates the star, or, if no star is marked, the declination and right ascension of the planet observed.

The positions of the planets can be plotted on the globe with a soft pencil, and if this is done it will only be necessary to alter their positions as follows:

Jupiter	every 3 months.
Saturn	every 2 months.
Mars and Venus	every 2 weeks.

It is a good plan to set the star globe and decide upon suitable stars *before* morning and evening twilight. To do this it is necessary to work out the approximate right ascension of the meridian for the time of the proposed observations, and then to set the globe in the way described.

By means of the brass cage, the altitude and bearing of the selected stars can be read off and noted.

What Star Is It? This book is supplied with each set of charts. By entering the tables with the observed altitude and the bearing of the star or planet, the right ascension and declination are found. Full particulars of the working are given in the book.

Procedure for Morning and Evening Observations of Stars and Planets

1. Prepare the star globe beforehand.
2. Choose three or more stars and planets to give the best cuts. Two should be about 90° apart. The best combination is, if possible, four stars, one north, one south, one east and one west,

because by using opposite horizons any abnormal refraction error should be cut out.

3. When choosing stars, note the weather and where the horizon is likely to be clearest.

4. Make a list of the approximate altitudes and bearings of the chosen stars and a rough sketch showing the bearings relative to the course of the ship. This will be a help when the time comes to look for them, and it is a good plan to set on the sextant the altitude of the brightest star chosen. Then, knowing the approximate bearing relative to the ship's head, look through the star telescope and sweep the horizon at this point. The star will frequently be found before it is visible to the naked eye, at which time the horizon is still good.

An ability to use this method is invaluable if there is broken cloud, for then a star may be visible only for a few moments. It is possible to take sights in this way without seeing the stars with the naked eye.

NOTE. This is the best method of finding Polaris.

Taking Observations

1. *In clear weather.* Take observations from the highest convenient position. (Upper bridge.)

2. *In fog, haze or mist.* Take observations from the lowest convenient position. (Quarterdeck.)

3. *With an indistinct, cloudy or hazy Sun* the perimeter of the Sun's disc is uncertain and it is more accurate to bisect the disc on the horizon than to make the lower limb touch the horizon. If this is done the altitude corrections, less that for semi-diameter, must be applied separately.

4. When possible check the sextant for side error before taking sights.

5. When possible take the index error *before* and *after* sights.

6. When observing the Sun, use sufficiently strong shades to avoid any possibility of dazzling.

7. When possible take observations of a heavenly body in sets of three or five, at approximately equal time-intervals.

8. Having brought the heavenly body to the horizon, always swing the sextant a few degrees each side of the vertical plane to make the body appear to describe the arc of a circle. This arc should then be raised or lowered by means of the tangent screw until it just touches the horizon. The observed altitude is measured at this point.

An alternative method is to bring the heavenly body down to the horizon and then note whether it is rising or setting. (If the body is west of the meridian it will be setting, if east of the meridian it will be rising.) If it is setting, move the tangent screw until the object is slightly above the horizon; then, leaving the sextant set, swing it gently from side to side until the star or limb just

touches the horizon. If it is rising, move the tangent screw until the object is slightly below the horizon, and carry out this same procedure.

9. When the horizon is poor, it is essential to take several altitudes of each body and to set the sextant to a given increase or decrease of altitude between each observation. If the time intervals are not approximately equal, the sights should be either discarded or used with extreme caution.

10. When reading the sextant, do not hold it sideways to the light but let the light come straight along the index bar to the vernier.

11. Having taken a set of observations of a star or planet, the identity of which is uncertain, take a compass bearing of it.

12. Make sure that the minute and second hands of the deck watch are ' lined up ' so that there can be no possibility of an error in the reading of the minute hand. If times are being taken by an assistant, it is advisable to check the minute hand yourself.

Times should be read to the nearest second. It is useful to be able to count in seconds so that, if there is no one available to take times, you can walk to the chart table counting the seconds and there read the deck watch.

13. Sometimes difficulty is found in bringing a star down to the horizon. When this happens a good plan is to reverse the sextant in the hand and look direct at the star with the index bar at zero. Bring the horizon *up to the star* ; then reverse the sextant and proceed in the normal manner.

14. *When the ship is rolling heavily* the rapidly changing dip may be reduced, and more accurate observations obtained, by taking them from a position close to the amidship line of the ship.

15. Observe stars as early as possible at evening twilight and as late as possible at morning twilight.

APPENDIX III

EXAMPLES OF SIGHTS TO FIND THE OBSERVED POSITION

By:
1. Sun—run—meridian altitude.
2. Moon—run—Sun.
3. Planet—star—Polaris.

Extract from The Nautical Almanac

APRIL, 1937

THE SUN
Saturday 3

G.M.T.	*R*	Dec.	*E*
h	h m	°	h m
00	12 43 37·4	N. 5 04·0	11 56 26·3
02	12 43 57·1	5 05·9	11 56 27·8
04	12 44 16·8	5 07·8	11 56 29·3
06	12 44 36·5	5 09·8	11 56 30·8
08	12 44 56·2	5 11·7	11 56 32·2
10	12 45 15·9	5 13·6	11 56 33·7
12	12 45 35·7	5 15·5	11 56 35·2
14	12 45 55·4	5 17·4	11 56 36·7
16	12 46 15·1	5 19·3	11 56 38·2
18	12 46 34·8	5 21·3	11 56 39·7
20	12 46 54·5	5 23·2	11 56 41·1
22	12 47 14·2	5 25·1	11 56 42·6

MOON'S RIGHT ASCENSION AND DECLINATION
Saturday 3

G.M.T.	R.A.		Dec.	
h	h m			
00	17 59	259	S. 22 19·8	5·3
02	18 03	260	22 14·5	5·9
04	18 08	259	22 08·6	6·2
06	18 12	260	22 02·4	6·7
08	18 16	259	21 55·7	7·1
10	18 21	260	21 48·6	7·6
12	18 25	259	21 41·0	8·0
14	18 29	260	21 33·0	8·4
16	18 34	259	21 24·6	8·9
18	18 38	259	21 15·7	9·2
20	18 42 39	258	21 06·5	9·7
22	18 46 58	259	S. 20 56·8	10·2

Date	VENUS R.A.		VENUS Dec.		VENUS Meridian Passage
	h m s	s	° ′	′	h m
Thur. 1	02 02 20	50	N. 20 13·8	1·5	13 24
Fri. 2	02 01 30	59	20 12·3	2·8	13 19
Sat. 3	02 00 31	67	20 09·5	4·2	13 14
Sun. 4	01 59 24		20 05·3		13 09

Star's Name	Mag.	R.A.	Dec.
α Persei .. .. .. *Mirfak*	1·9	03 19 50	N. 49 38·4

EXAMPLE OF FINDING
SUN—RUN—
(A full explanation of this

RECOMMENDED ARRANGEMENT

D.W.T.	Deck Watch Time.	Sext. alt.	Sextant altitude.
Error	plus if slow ; minus if fast.	I.E.	Index Error.
G.M.T.	Greenwich Mean Time.	Obs. alt.	Observed altitude.
Long.	Plus if east : minus if west.	Corr^n.	*Inman's Tables*
L.M.T.	Local Mean Time.	True alt.	True altitude.
E	for G.M.T. Always plus.	T.Z.D.	90° minus true altitude.
H.A.T.S.	(i) Hour Angle True Sun.	C.Z.D.	from natural haversine (xi)
Lat.	(ii) Latitude of E.P. or D.R. position.	Intercept	AWAY if T.Z.D. is greater than C.Z.D. and vice versa.
Dec.	(iii) Declination for G.M.T.	S.T.B.	Sun's True Bearing from *Weir's Diagram* or *Azimuth Tables*.

(iv) For same names subtract (ii) and (iii)
For opposite names add (ii) and (iii)
(v) log haversine (i)
(vi) log cosine (ii)
(vii) log cosine (iii)

(viii) Sum of (v), (vi) and (vii)

(ix) natural haversine (iv)
(x) natural haversine (viii)

(xi) Sum of (ix) and (x)

Z.T.	Zone Time of meridian passage.
Zone Corr^n.	Zone.
G.D.	Greenwich Date of meridian passage.
Dec.	(i) Declination for G.D.
Lat.	(ii) Latitude of E.P. or D.R. position
C.Z.D.	(iii) For same names subtract (i) and (ii) For opposite names add (i) and (ii)
Sext. alt.	Sextant altitude.
I.E.	Index Error.
Obs. alt.	Observed altitude.
Corr^n.	*Inman's Tables.*
True alt.	True altitude.
T.Z.D.	90° minus true altitude.
C.Z.D.	(iii)
Intercept	AWAY if T.Z.D. is greater than C.Z.D. and vice versa.
S.T.B.	Sun's True Bearing from *Weir's Diagram* or *Azimuth Tables.*

THE OBSERVED POSITION

MERIDIAN ALTITUDE

work is given in Volume II)

EXAMPLE

3rd April 1937. Course 070°. Speed 12 knots. At about 0830(+2) in E.P. 51°15′N. 29°45′W., the sextant alt. ☉ was 26°10′ when the D.W. showed $10^h29^m50^s$.

At about 1200(+2) the sextant meridian alt. ☉ was 43°32′·4. Error of D.W. 3^s slow on G.M.T. Index error +2′·5. Height of eye 40 feet.

Required the ship's observed position at the time of meridian altitude.

	h m s		
D.W.T.	10 29 50	Sext. alt. ☉	26°10′·0
Error	3 slow	I.E. +	2′·5
G.M.T.	10 29 53 3rd April	Obs. alt. ☉	26°12′·5
Long. W.	1 59 00	Corrⁿ. +	8′·0
L.M.T.	8 30 53	True alt. ☉	26°20′·5
E	11 56 34·1	T.Z.D.	63°39′·5
H.A.T.S.	20 27 27·1	C.Z.D.	63°34′·3
Lat. N.	51°15′	Intercept	5′·2 AWAY
Dec. N.	5°14′·1	S.T.B.	117°
Lat.—Dec.	46°00′·9		

9·301 13
9·796 52
9·998 19

9·095 84

·124 69
·152 77

·277 46

When it is intended to take a meridian altitude sight, it is necessary to work out the time of meridian passage. The method of doing this is fully explained in Volume II.

In this example the time of meridian passage is 1158(+2).

To find the E.P. at 1158(+2) by *Traverse Table.*

	N.	E.	W.
Intercept 5·2 away from 117°(N.63°W.)	2′·4		4′·6
Run: 3^h28^m at 12 knots=41′·6 course 070°	14′·2	39′·1	
	16′·6N.	39′·1E.	4′·6W.

d'lat.=16′·6N. dep=34′·5E.
mid lat. 51°23′N. ∴d'long=55′·3E.

∴E.P. at 1158(+2) $\begin{cases}51°31′·6N.\\28°49′·7W.\end{cases}$

Z.T.	1158(+2)
Zone Corrⁿ.	+200
G.D.	1358 3rd April
Dec. N.	5°17′·4
Lat. N.	51°31′·6
C.Z.D.	46°14′·2
Sext. alt.	43°32′·4
I.E. +	2·5
Obs. alt.	43°34′·9
Corrⁿ. +	8′·9
True alt.	43°43′·8
T.Z.D.	46°16′·2
C.Z.D.	46°14′·2
Intercept	2′·0 AWAY
S.T.B.	180°

To find the observed position at 1158(+2)

From figure 168
d'lat=2′·0N. dep=1′·0E.
mid lat 50°30′N. ∴d'long=1′·6E.

∴Observed position at 1158(+2) $\begin{cases}51°33′·6N.\\28°48′·1W.\end{cases}$

NOTE. An alternative method of working out a meridian-altitude sight is explained in Volume II.

EXAMPLE OF FINDING

MOON—

(A full explanation of this

RECOMMENDED ARRANGEMENT

D.W.T.	Deck Watch Time.	Sext. alt. ☾	Sextant altitude.
Error	plus if slow ; minus if fast.	I.E.	Index error.
G.M.T.	Greenwich Mean Time.	Obs. alt. ☾	Observed altitude.
Long.	plus if east ; minus if west.	Corr^n.	from *Inman's Tables.*
L.M.T.	Local Mean Time.	True alt. ☾	True altitude.
R	for G.M.T. Always plus.	T.Z.D.	90° minus true altitude.
R.A.M.	R.A. Meridian.	C.Z.D.	from natural haversine (xi)
R.A.	R.A. Moon for G.M.T. Always minus.	Intercept	AWAY if T.Z.D. is greater and vice versa.
H.A.	(i) Moon's Hour Angle.	T.B.	from *Weir's Diagram* or *Azimuth Tables.*
Lat.	(ii) Latitude of E.P. or D.R. position.		
Dec.	(iii) Moon's declination for G.M.T.		

(iv) for opposite names add (ii) & (iii)
for same names subtract (ii) & (iii)
(v) log haversine (i)
(vi) log cosine (ii)
(vii) log cosine (iii)
(viii) sum of (v) (vi) & (vii)
(ix) natural haversine (viii)
(x) natural haversine (iv)

(xi) sum of (ix) and (x)

The ship's run can be :

(*a*) plotted directly on a Mercator chart or a plotting chart.

(*b*) calculated by means of the *Traverse Table.*

D.W.T.	Deck Watch Time.	Sext. alt ☉	Sextant altitude.
Error	plus if slow : minus if fast.	I.E.	Index error.
G.M.T.	Greenwich Mean Time.	Obs. alt. ☉	Observed altitude.
Long.	plus if east : minus if west.	Corr^n.	*Inman's Tables.* Always plus.
L.M.T.	Local Mean Time.	True alt. ☉	True altitude.
E	for G.M.T. Always plus.	T.Z.D.	90° minus true altitude.
H.A.T.S.	(i) Hour Angle True Sun.	C.Z.D.	from natural haversine (xi)
Lat.	(ii) Latitude of E.P. or D.R. position.	Intercept	AWAY if T.Z.D. is greater than C.Z.D. and vice versa.
Dec.	(iii) Declination for G.M.T.	S.T.B.	Sun's True Bearing from *Weir's Diagram* or *Azimuth Tables.*

(iv) For same names subtract (ii) & (iii)
For opposite names add (ii) & (iii)
(v) log haversine (i)
(vi) log cosine (ii)
(vii) log cosine (iii)
(viii) sum of (v) (vi) & (vii)
(ix) natural haversine (iv)
(x) natural haversine (viii)

(xi) sum of (ix) and (x)

THE OBSERVED POSITION

RUN—SUN

work is given in Volume II)

EXAMPLE

3rd April, 1937. Course 070°. Speed 12 knots. At about 0500(+1) in E.P. 50°10′N., 14°50′W., the sextant alt. ☾ was 16°25′·0 when the D.W. showed $05^h59^m40^s$.

At about 0740(+1) the sextant alt. ⊙ was 19°48′·0 when the D.W. showed $08^h40^m05^s$. D.W. error 5^s slow on G.M.T. Index Error +1′·5. Height of eye 40 feet. Moon's horizontal parallax 54′·8.

Required the ship's observed position at 0740(+1).

	h m s			
D.W.T.	05 59 40		Sext. alt. ☾	16°25′·0
Error slow	05		I.E. ∓	1′·5
G.M.T.	05 59 45	3rd April	Obs. alt. ☾	16°26′·5
Long. W.	59 20		Corrⁿ. ∓	58′·2
L.M.T.	05 00 25		True alt. ☾	17°24′·7
R	12 44 36·5		T.Z.D.	72°35′·3
R.A.M.	17 45 01·5		C.Z.D.	72°27′·7
R.A.	18 12 22·5		Intercept	7′·6 AWAY
H.A.	23 32 39·0		T.B.	173°

Lat. N.	50°10′·0
Dec. S.	22°02′·4
Lat. + Dec.	72°12′·4
	7·550 97
	9·806 56
	9·967 04
	7·324 57
	·002 11
	·347 21
	·349 32

To find the E.P. at 0740(+1) by *Traverse Table*

	N.	E.	W.
Intercept: 7′·6 away from 173°(N.7°W.)	7′·5		0·9
Run: 2^h40^m at 12 knots = 32′ course 070°	10′·9	30′·1	
	18′·4N.	30′·1E.	0′·9W.

d′lat = 18′·4 N. dep = 29′·2E.
mid lat 50°19′N. d′long = 45′·7E.

∴ E.P. at 0740(+1) { 50°28′·4N. 14°04′·3W.

	h m s			
D.W.T.	08 40 05		Sext. alt. ⊙	19°48′·0
Error slow	05		I.E. +	1′·5
G.M.T.	08 40 10	3rd April	Obs. alt. ⊙	19°49′·5
Long. W.	56 17·2 W.		Corrⁿ. +	7′·2
L.M.T.	07 43 52·8		True alt. ⊙	19°56′·7
E	11 56 32·7		T.Z.D.	70°03′·3
H.A.T.S.	19 40 25·5		C.Z.D.	70°11′·5
Lat. N.	50°28′·4		Intercept	8′·2 TOWARDS
Dec. N.	5°12′·3		S.T.B.	106½°
Lat. − Dec.	45°16′·1			
	9·459 17			
	9·803 76			
	9·998 21			
	9·261 14			
	·182 45			
	·148 11			
	·330 56			

From figure 169
d′lat = 1′·1N. dep. = 8′·9E.
mid. lat = 50°29′N. d′long = 14′·0E.

∴ Ship's observed position at 0740(+1) { 50°29′·5N. 13°50′·3W.

EXAMPLE OF FINDING

PLANET—STAR—

(A full explanation of this

RECOMMENDED ARRANGEMENT

D.W.T.		Deck Watch Time.
Error		plus if slow ; minus if fast.
G.M.T.		Greenwich Mean Time.
Long.		plus if east ; minus if west.
L.M.T.		Local Mean Time.
R		for G.M.T. Always plus.
R.A.M.		Right Ascension of the Meridian.
R.A.		Right Ascension of the star for G.M.T. Always minus.
H.A.	(i)	Hour Angle. If over 24 hours subtract 24 hours.
Lat.	(ii)	Latitude of the E.P. or D.R. position.
Dec.	(iii)	Star declination for the month. (The declination of a planet should be taken out for G.M.T.)
	(iv)	for opposite names add (ii) and (iii) for same names subtract (ii) and (iii)
	(v)	log haversine (i)
	(vi)	log cosine (ii)
	(vii)	log cosine (iii)
	(viii)	sum of (v), (vi) and (vii)
	(ix)	natural haversine of (viii)
	(x)	natural haversine of (iv)
	(xi)	sum of (ix) and (x)
Sext. alt.		Sextant altitude.
I.E.		Index error.
Obs. alt.		Observed altitude.
Corr^{n}.		from *Inman's Tables.* Always minus.
Alt.		True altitude.
T.Z.D.		90° minus true altitude.
C.Z.D.		Calculated Zenith Distance. From natural haversine of (xi)
Intercept		AWAY if the T.Z.D. is greater than the C.Z.D. and vice versa.
		True Bearing from *Azimuth Tables* or *Weir's Diagram.*

(i) When a planet sight is worked, it is necessary to interpolate to obtain the accurate declination and right ascension for G.M.T.

(ii) The corrections to the pole star altitude are made in the following order

(i) Index Error

(ii) Dip and Refraction taken from *Inman's Tables*

(iii) Pole Star table I
(iv) ,, ,, ,, II
(v) ,, ,, ,, III

} from the *Nautical Almana*

THE OBSERVED POSITION
POLARIS (3 STARS)
work is given in Volume II)

EXAMPLE

3rd April 1937. Course 030°. Speed 25 knots. At about 1730(−8) in E.P. 20°10′N., 120°40′E., the following observations of heavenly bodies were obtained :

D.W.T. h m s	Sextant altitude	Approximate bearing
9 20 04	20°37′·3	360° (Polaris) From Star Globe
9 24 10	45°04′·6	320° (Mirfak) From Star Globe
9 29 18	30°11′·5	280° (Venus) From Star Globe

Error of D.W. 12s slow on G.M.T. Index Error +2′·5. Height of eye 24 feet. Required the ship's observed position at 1730(−8).

	Polaris h m s		Mirfak h m s		Venus h m s
D.W.T.	9 20 04		9 24 10		9 29 18
Error slow	12	slow	12	slow	12
G.M.T.	9 20 16 3rd April		9 24 22 3rd April		9 29 30 3rd April
Long.	8 2 40E.		8 2 40E.		8 2 40E.
L.M.T.	17 22 56		17 27 02		17 32 10
R	12 45 9·3		12 45 10·1		12 45 10·9
R.A.M.	6 08 05·3		30 12 12·1		30 17 20·9
R.A.			3 19 50		2 00 04
H.A.			2 52 22·1		4 17 16·9
Lat.			20°10′·0N.		20°10′·0N.
Dec.			49°38′·4N.		20° 7′·8N.
Lat.–Dec.			29°28′·4		0°02′·2
			9·129 92		9·452 30
			9·972 52		9·972 52
			9·811 30		9·972 63
			8·913 74		9·397 45
			·081 99		·249 72
			·064 71		·000 00
			·146 70		·249 72
Sext. alt.	20°37′·3		45°04′·6		30°11′·5
I.E.	+ 2′·5		+ 2′·5		+ 2′·5
Obs. alt.	20°39′·8		45°07′·1		30°14′·0
Corr^n.	- 7′·3		− 5′·8		− 6′·5
True alt.	20°32′·5		45°01′·3		30°07′·5
Tables I & II	− 24′·0	T.Z.D.	44°58′·7		59°52′·5
	20°08′·5	C.Z.D.	45° 2′·5		59°57′·8
Table III	0	Intercept	3′·8 TOW		5′·3 TOWARDS
Latitude	20°08′·5	T.B.	321°		282°

Figure 170 shows the plotting of the fix.
The position lines are run on to 1730(−8) :

Polaris 4′·0 on the course 030°
Mirfak 2′·3 ,, ,, ,, ,,
Venus 0′·2 ,, ,, ,, ,,

From figure : d′lat = 2′·0N. dep = 5′·0W.
mid lat = 20°11′N.
d′long = 5′·3W.

∴ Ship's observed position at 1730(−8) is { 20°12′·0N 120°34′·7E.

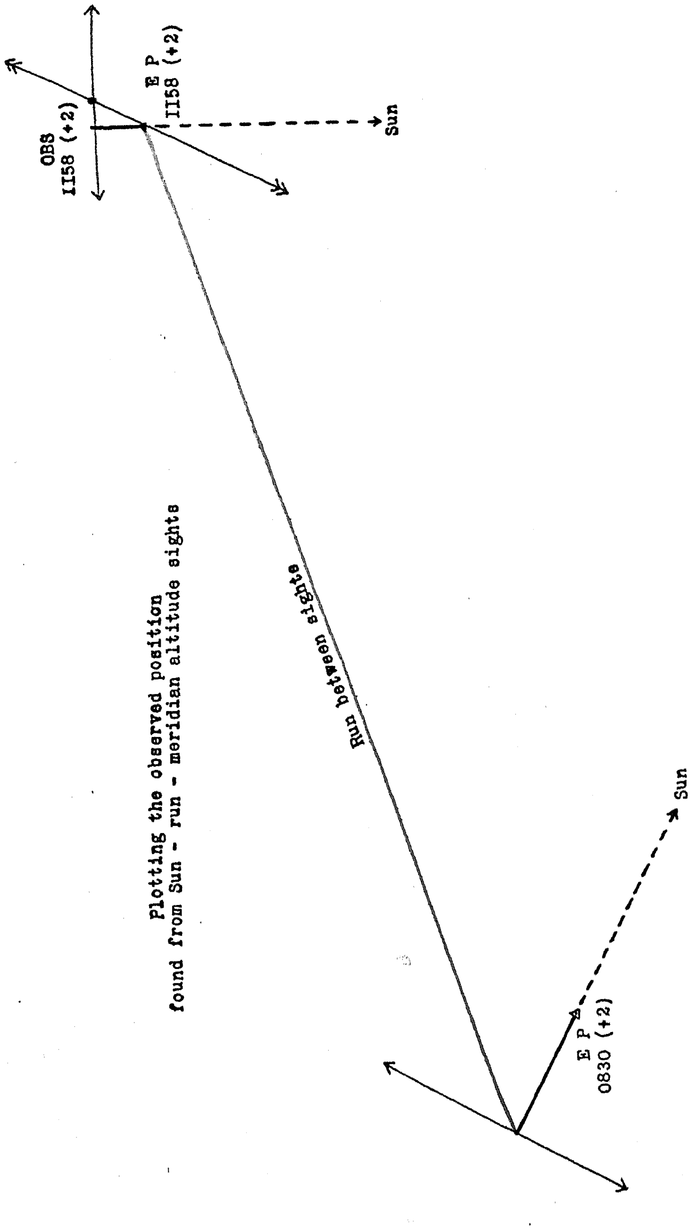

OBS
II58 (+2)
E P
II58 (+2)
Sun
Plotting the observed position
found from Sun - run - meridian altitude sights
Run between sights
E P
0830 (+2)
Sun

FIGURE 168.

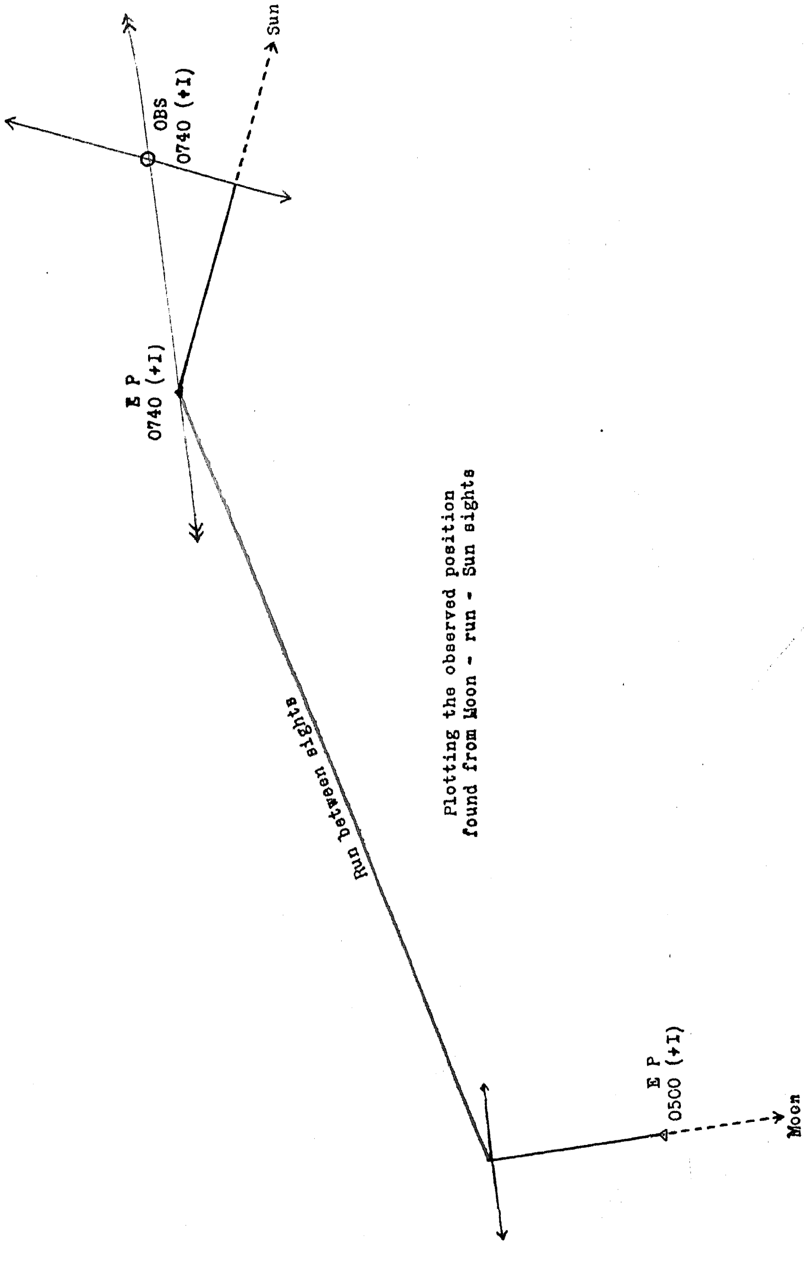

Sun
OBS
0740 (+I)
E P
0740 (+I)
Run between sights
Plotting the observed position
found from Moon - run - Sun sights
E P
0500 (+I)
Moon

FIGURE 169.

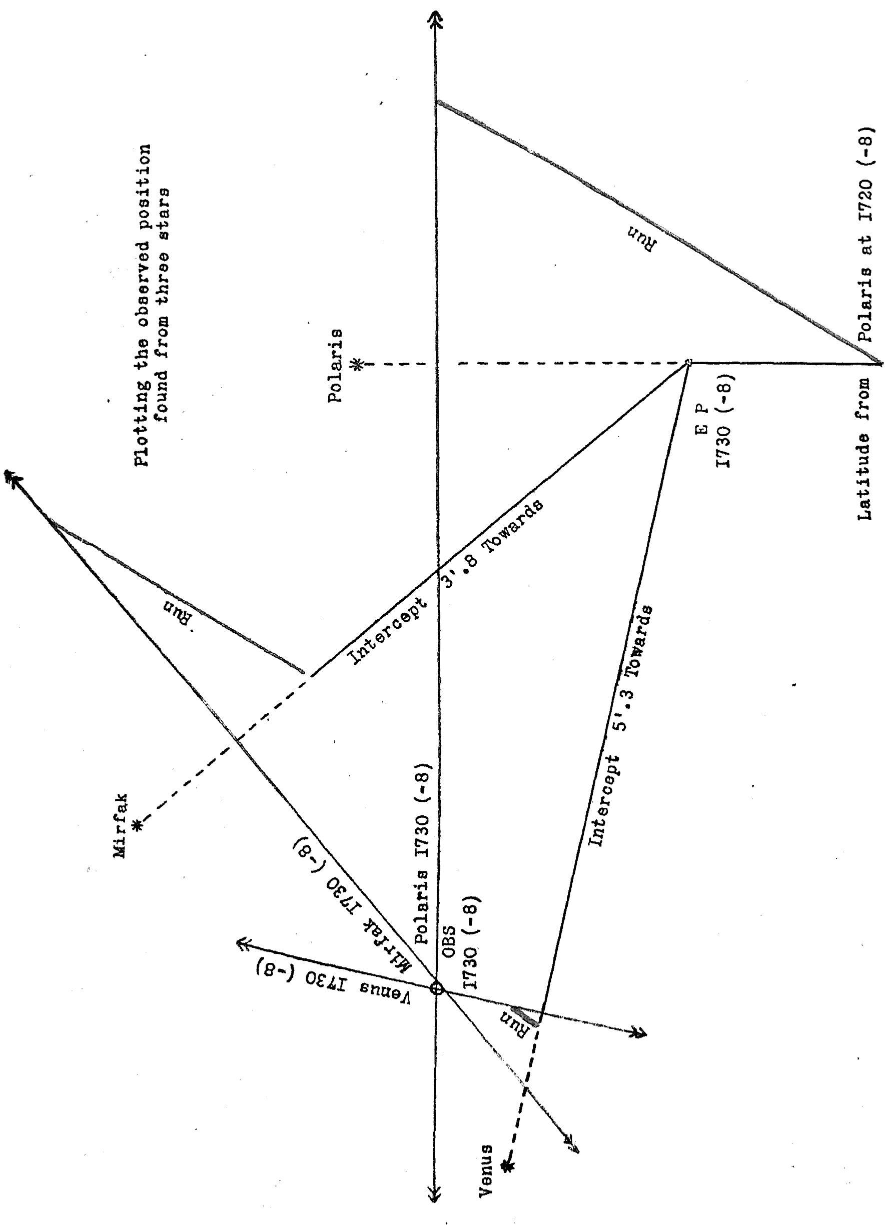

Plotting the observed position
found from three stars
Polaris
Run
Latitude from Polaris at I720 (-8)
E P
I730 (-8)
Intercept 3'.8 Towards
Run
Mirfak
Intercept 5'.3 Towards
Polaris I730 (-8)
Mirfak I730 (-8)
OBS
I730 (-8)
Venus I730 (-8)
Run
Venus

FIGURE 170.

APPENDIX IV

K.R. & A.I. AFFECTING THE NAVIGATING OFFICER

Regulations Marked with an (O) also Affect the Officer of the Watch

Anchors, Cables, etc.

		Article
	Canvas gear—reports from Boatswain	1502 & 1218
	Chain cables—preservation of	1100
	responsibility for inboard end	1216
	not to be lowered at excessive speed	1961
	survey of	1961
(O)	Hawse, state of	1152 & 1216
	Loss of, and recovery	1101–2 ; 1130
	Rigging, responsibility re	1216
	Rudder signals, responsibility re	1216

Books

	Disposal of	863 & 1208
(O)	Fishing Vessel Log	1168
	Gyro compass Log	1187
	Navigational Data Book	1187 & 1206
(O)	Sailing Directions—to be consulted	1161
(O)	Ship's log—entries ; disposal of ; responsibility for	1208–9 & 1313
	Work and Note Book	1211

Courses, Syllabuses, Instruction, Examination. App. XII

General

	Accountant Officer—Performance of duties by Navigating Officer ;	1464
	Anchoring ; Safe Berth ; Sounding round ship ;	1165
(O)	Approaching land ; Soundings ; Standing off ;	1161–3–4
(O)	Approaching powder magazines	1176

RETURNS TO BE RENDERED BY THE NAVIGATING OFFICER

When to be rendered	Subject	To whom rendered
Weekly	Ship's log	Captain for signature.
Monthly	Ship's log	Senior Officer of the squadron who will forward it to the Commander-in-Chief of the Station for transmission to the Royal Victoria Yard, Deptford.
Quarterly	(i) Pilotage return	Director of Navigation, Admiralty.
	(ii) Gyro Compass report.	Director of Compass Establishment, Slough, except for ships in the Mediterranean station who send the report in duplicate to the Superintendent of Gyro Compasses, Malta.
Annually on 31st December.	(i) Chronometer return.	Hydrographer of the Navy.
	(ii) Heels and rolls by vertical battens.	Commander-in-Chief of the Station.
	(iii) Deviation of the Compass.	Director of the Compass Establishment, Slough. Only forwarded if no compass return has been made during the past twelve months. (See Periodic returns.)
Periodically	(i) Deviation of the Compass.	Director of the Compass Establishment, Slough. Forwarded: (*a*) after every swing for adjustment of compasses. (*b*) after large structural alterations near the bridge.
	(ii) Hydrographic notes.	One copy to the Hydrographer of the Navy. One copy to the Commander-in-Chief of the Station.
	(iii) Turning Trials	Secretary of the Admiralty, within six months of first commissioning.
On supersession	(i) Pilotage return	See quarterly returns.
	(ii) Chronometer return.	See annual returns.
	(iii) Receipt for chart folios.	Admiralty Chart Establishment, Cricklewood.
	(iv) Store account	Central Storekeeping Officer.
On paying off	(i) Pilotage return	See quarterly return.
	(ii) Gyro log	Director of Compass Establishment, Slough.
	(iii) Chronometer return.	See annual returns.
	(iv) Receipt for charts.	See K.R. and A.I. 736.
	(v) Store account	See returns on supersession.
	(vi) Ship's log	See monthly return.
	(vii) Fishing vessel log.	Secretary of the Admiralty.
	(viii) Heels and rolls by vertical battens.	See annual returns.
	(ix) Navigational Data book.	Admiral Superintendent of the Dock- [illegible] ention until such time as the ship recommissions.

APPENDIX V

HINTS TO THE OFFICER RESPONSIBLE FOR THE NAVIGATION OF A SHIP

General

Duties of the Navigating Officer

The duties of the navigating officer are laid down in K.R. and A.I. Chapter XXXIII.

Additional Responsibilities (K.R. and A.I. 1216–1219)

Rigging.
Steering signals.
Cables.
Hawse when moored.
Sounding machines, logs and lead lines.
Stowage of the ship.
Sails and canvas.
Inspection of store-rooms.

Handling the Ship. The Captain will normally handle the ship, but *it is essential that the navigating officer should have a thorough knowledge of the capabilities of the ship and of O.U.* 5274, '*Remarks on Handling Ships*'.

In Harbour

1. Keep the charts and publications corrected up to date from the latest *Notices to Mariners.*
2. Supervise the quartermasters. (A smart quarterdeck staff is an indication of a smart ship.)
3. Supervise the checking of ship's clocks.
4. Check the chronometer rates by time signals at intervals not exceeding ten days.
5. Inspect the gyro-compass room and see that the care-and-maintenance routine is being carried out.

Daily :

(*a*) write up the fair log.
(*b*) wind and compare the chronometers and watches.

At Open Anchorage

1. Make arrangements to receive the weather reports necessary for plotting a daily synoptic chart and obtaining a weather forecast.

2. If there are few charted objects for fixing the ship, 'shoot up' uncharted marks ashore to assist in fixing, should it come on to blow.

3. Obtain any local information which may be useful to the Hydrographer for future charts and publications.

On Commissioning or on Joining a Ship

1. Draw central stores.
   (*a*) Check the lead lines.
   (*b*) Have chemical tubes available for use and see they are not over-age.

2. Draw and check the charts and all navigational publications.

3. Draw chronometers and watches. Application should have been made to the Hydrographer prior to your arrival. (K.R. and A.I. Article 1193.)

4. Correct the charts and publications up to date and rate the chronometers.

5. Carry out a gyro-compass performance test.

6. Test sounding booms and sounding machines.

7. Make yourself thoroughly acquainted with the alternative steering arrangements.

8. Note and test all communications between the bridge and various positions. (Engine rooms, steering positions, lifebuoy sentry, etc.)

9. Study carefully all the information in the *Navigational Data Book.*

In a new ship start a new book and obtain as much information as possible from the naval constructors. If the ship is recommissioning after being out of commission, the book will have to be drawn from the Admiral Superintendent of the Dockyard, who will have held it.

10. Make certain that the quartermasters know their duties. (Steering orders, changing over steering positions, writing up the deck log, etc.)

Before Proceeding to Sea

Plan. Prepare a plan for the forthcoming passage. This will often avoid anxiety at sea. The following points should be considered :

1. The time of passing through channels and narrow water and the tidal stream or current to be expected.

2. The probable positions of the ship at dusk and throughout the night. By arranging the times of arrival and departure it is often possible to avoid placing the ship in a difficult position, such as arriving at the entrance or having to pass through a narrow unlighted channel during darkness.

3. If your passage is through tidal waters, work out the tidal streams for the whole passage.

Do not make out your plan for full economical speed because you are more likely to be late than early. Speed can always be reduced in order to adhere to the pre-arranged time of arrival. Only in exceptional circumstances should economical speed be exceeded or the time of arrival altered.

Points to be Attended to :

1. Draw from the folios the necessary charts and read through the *Sailing Directions* and ' W ' messages concerned.
2. Give the necessary instructions for starting the gyro compass.
3. Overhaul the sounding machine and make certain you have a supply of fresh chemical tubes on board.
4. Test through all the bridge communications.
5. Advise your Captain to have an understanding with the engine room regarding the procedure to be followed with engine-room telegraphs about which there must be *no possible misunderstanding*. *The revolution telegraph* should always be at *zero* unless it is to be obeyed.
6. Test the echo-sounding gear and patent log.
7. Check the navigational rangefinders.

Regulations for the Movements of Ships in and out of Dockyard Ports are given in K.R. and A.I. Article 721.

The Employment of Pilots and the Relations between the Captain and the Pilot are given in K.R. and A.I. Article 1179 to 1185 and in Chapter IV of O.U. 5254, *Remarks on Handling Ships*.

Tonnage. At various ports, both British and foreign, the rates payable to local pilots, depend upon the ship's tonnage, either displacement, gross, or net (register). Each of these measurements is to be given on form S.21.

Displacement Tonnage. This is the weight of water displaced by the ship, and is thus equal to the weight of the ship.

Displacement = volume of water displaced in cubic feet divided by 35 or 36 according as the water is salt or fresh.

The following are modifications of the displacement tonnage.

1. **Navy List Displacement.** The estimated displacement with average fuel and stores on board.

This was given in the *Navy List* before the 1923 Washington treaty. It is now an obsolete measurement, but is still quoted for older ships in the *Navy List* in parenthesis as " (Displacement by previous national rules . . .)".

2. **Standard Displacement** (Washington treaty). The displacement of the ship complete, fully manned, engines, armament,

ammunition, provisions, all stores, equipment and fresh water for crew, but *without* fuel or reserve feed water.

This is the displacement tonnage now quoted in the *Navy List*.

Gross Tonnage. The internal capacity of the ship, including permanent closed-in deck houses, reckoned in tons of 100 cubic feet. (In a warship this works out at a rough average of 60% of the standard displacement.)

Net or Register Tonnage. This is the tonnage shown in the *Register Book* which is kept by the Society of Lloyd's Register. It is similar to gross tonnage, except that certain fuel, machinery and crew spaces are deducted, the object being to arrive at the cargo-carrying capacity.

Different nations have different rules for measuring net tonnage, the principal being the British and Danube.

Revised Net Tonnage. This is worked out by the Admiralty and inserted on a slip of paper at the top of the Suez Canal certificate in the *Ship's Book* (but not used for Suez Canal). The slip is worded as follows:

"For the purposes of dock and harbour dues in the United Kingdom, the net or register tonnage of this vessel is .... ; by the authority of the Lords Commissioners of the Admiralty."

NOTE. (*a*) Revised net tonnage is NOT to be used on form S.21.
(*b*) Revised net tonnage is used for docking at Bombay.

Exceptions. There are certain exceptions to the above rules, the most notable of which occur when on passage through the following canals.

Suez Canal. Every ship is supplied with a Suez Canal certificate giving her tonnage and other details for assessment of dues for transit through the canal. The tonnage is net or register tonnage assessed by Danube rules.

Panama Canal. Dues are based on displacement tonnage.

Kiel Canal. Dues are based on the gross tonnage in the *Ship's Book* divided by 1·7.

The Board of Trade Tonnage Certificate, which shows the gross, the net or register, and the Danube tonnage, is supplied to all of H.M. ships on completion or re-measurement after structural alterations. It should be kept in the *Ship's Book*.

On Leaving Harbour

Check the Deviation of the Compass by transits, particularly when a long course is to be set at the entrance. If the weather is thick and it is difficult to observe the rear object, get someone to observe the transit through binoculars while you take the bearing of the nearer object.

See that the correct speed correction is applied to the master gyro compass for any alteration in the ship's speed.

When passing buoys, note the direction of the tidal stream.

Check the buoys as you pass them, and remember that the shape is more important than the colour.

Keep to that side of the channel which lies on the starboard hand.

NOTE. It is advisable on the first occasion of proceeding to sea at night to be sure that the instructions laid down in K.R. and A.I. 1178 concerning lights from portholes and scuttles are being observed.

Red or *Green* materials are not allowed to be used for curtains or lampshades.

Coasting and in Fog and Thick Weather

ALWAYS think ahead and work to a plan.

NEVER be too confident about your ship's position.

THE PRESENT POSITION OF THE SHIP SHOULD ALWAYS BE ON THE CHART.

NOTE CAREFULLY all the procedure detailed in Chapter VI.

On Ocean Passage

1. The last fix on leaving land, the 'departure fix', is important because much may depend on it, but if the weather is thick, remember the principle explained in Chapter VI, *outward bound, don't run aground.*

2. Take every opportunity of fixing the ship's position astronomically. A normal series should be three or four stars at morning, and again at evening twilight. These are sufficient to give the ship's position accurately. Sun sights for position line a.m. and p.m. and a Sun sight for latitude about midday.

3. Do not take sights if the horizon is so bad that you cannot trust your result; you may get a position line widely different from your estimated position, the latter being preferable.

4. Remember to adjust your ship's clocks for zone time.

5. Take a daily weather report and plot a synoptic chart.

6. Make weather reports at times laid down in the *Weather Manual.*

7. Check your compasses by azimuths of heavenly bodies, after each alteration of course and at least once every twelve hours.

On Making Land

The precautions to be taken on making the land are laid down in K.R. and A.I. Articles 1163 and 1164.

Before Making a Landfall. *Always*:

1. have available the chart showing the neighbourhood for many miles around and showing all lights which may be seen.

2. work out the allowance for wind and tidal stream for the final approach.

3. work out the safe distance which soundings will give you from land.

On Approaching Land. *Always* :

1. take soundings.
2. have anchors cleared away.

Bear in mind the following points :

Estuaries. In fresh water the draught of the ship increases by about one-sixth of an inch per foot of draught; that is, the increase in inches is approximately one-sixth of the draught in feet.

Islands. Near the lee side of lofty islands the weather is generally clear of fog, mist and low cloud. Therefore, when a landfall is made in thick weather, better visibility may be experienced if the approach is made from leeward.

On Entering Harbour

Before a harbour is entered for the first time, the chart and books should have been studied to such an extent that each prominent mark is revealed without surprise in its expected shape and place. The charts and *Sailing Directions* frequently give sketches and pictures.

To identify an object, a transit with a known mark or with a tangent of the land will help.

Local Rules. It should be ascertained whether a vessel entering has to wait until ships leaving about the same time have cleared the channel. This information is given in the *Sailing Directions*.

If a channel has few or no aids to navigation and a tide across the course, it is clear that a ship making the passage in one hour, say, will encounter only half the risks of a ship going at a slower speed and taking two hours.

When allowance is made for a strong cross set, it may be necessary for the ship to be pointing a large number of degrees from the course to be made good. In these circumstances, should the ship be set off her course to be made good :

1. regain the line by a bold alteration of course.
2. when the line has again been reached, steer a course which will meet, more adequately than the original, the prevailing tidal stream or current.

Always :

1. have special sea-dutymen closed up in plenty of time.
2. note the points stated at the top of page 419.

On Anchoring and Mooring

Note caretully the information given in Chapter XI and consider the following points.

It is desirable to know :

1. How the ship behaves with reference to the wind when going slow speed ahead ?

2. Does she respond to the wheel when she has little headway without help from the engines ?

3. With beam winds, forces four to ten, what are the minimum speeds to maintain control, and does stopping the lee engine help ?

4. Will the ship obey her rudder at slow or even moderate astern speed, if making a sternboard with the wind ahead or on one bow ?

5. How does she behave when going astern into the wind ?

6. In what distances can the ship's way be stopped from economical and from slow ahead speeds ?

7. How is the ship best extricated from danger ahead—full speed astern, or wheel hard over ?

8. Statistics about tactical diameter—distance to reduce speed and stop engines for single anchor and for mooring ship and for approaching a buoy or jetty ?

NOTE. All the above information should be in the *Navigational Data Book*, except when a ship commissions for the first time.

When using a gyro compass, be sure that the correct latitude is set on the corrector mechanism and that the speed setting is altered as the ship reduces speed.

Keep a careful watch on the ship's head and check the *first* tendency to fall away or come up into the wind.

Use an anchor buoy because it may save a lot of trouble if the cable parts.

Take care, when using the anchor flags for letting go, that they are shown for a few seconds only before being lowered to let go the anchor.

Mooring

1. Ensure that the 1st anchor is let go in its correct position.

2. Let go the 2nd anchor from the bridge if there are good marks between 50° and 130° on either side at a distance of under one mile.

3. Remember that the correct *berth* is the important point, and this may necessitate a departure from the number of shackles ordered.

4. Never allow the ship to stop between letting go the anchors.

5. Guard against leeway and maintain adequate but not excessive way.

6. In a tideway, pay particular attention to the speed over the ground.

7. With the wind astern, put the wheel over just before letting go the second anchor to ensure that the bow pays off in the required direction.

8. If the 1st anchor has been let go slightly to one side of the correct line, it is sometimes possible to get the bows in the correct position, when middled, by steering across the correct line of anchors or by swinging the bows of the ship just before letting go the second anchor.

Anchoring or Mooring on a Ship

1. *When using a mooring board,* do not forget navigational dangers, clearing marks and clearing bearings.

2. Fix your position on the mooring board *as soon as possible* by range and bearing, and check your position on the mooring board as often as possible.

3. Plot the position of the bow and stern of the ship to be moored or anchored on because these may be useful on letting go the anchor.

4. Let go the anchor (when mooring the 1st anchor) by bearing *or* by distance from the foremast, stem or stern of the ship to be anchored on, *whichever is altering the more rapidly.*

On Return to Harbour

1. Analyse the previous passage and insert any data of interest in the *Navigational Data Book,* for example :

   (*a*) the speed by engine-room revolutions for the time out of dock.
   (*b*) any error of the logs.
   (*c*) any leeway experienced.
   (*d*) any compass deviations.

2. Write up the gyro compass log.

3. If any charts have been damaged or worn, demand new ones.

On the Approach of Bad Weather. Take steps to ensure that you are *always* informed by the officer of the watch or quartermaster on the *first signs* of the approach of bad weather. When these are reported, place the chart of the anchorage on the bridge and check the ship's position. Have a lead line on the quarterdeck to detect dragging. Start up the gyro compass.

Notice for Steam. The notice for steam depends upon circumstances. If close to a lee shore or in bad holding ground, suggest to your Captain that immediate notice for steam is necessary.

On Being Relieved

1. Prepare a plan of the turnover to ensure that your successor obtains all possible information concerning the ship.

2. Make certain that all the knowledge you have gained concerning the ship has been inserted in the *Navigational Data Book.*

3. Prepare supply, receipt and transfer notes for charts and chronometers.

4. Check through stores and O.U. books on loan and obtain a receipt note for the former.

5. Forward the returns detailed on page 414 in Appendix IV.

On Paying Off

1. Prepare supply and receipt notes and return charts and chronometers.

2. Inform the Director of the Admiralty Compass Establishment, Slough, as long as possible beforehand, of a suitable date for the inspection of the gyro compass.

3. The *Navigational Data Book* is to be handed to the Admiral Superintendent of the dockyard for custody until the ship recommissions.

4. Forward the returns as detailed on page 414.